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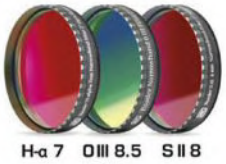

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This month's contributors include...

CHRIS LINTOTT
SKY AT NIGHT PRESENTER

Chris explains why the tidal streams left by galaxy mergers are pointing to the existence of dark matter. *Page 14*

ELIZABETH PEARSON
NEWS EDITOR

Do the worlds of a galaxy far, far away exist closer to home? Elizabeth hunts for the worlds of *Star Wars*. *Page 62*

STEVE RICHARDS
EQUIPMENT EXPERT

Following last month's advice on bias frames, this month Steve explain how to improve your shots with dark frames. *Page 84*

ANDERS THYGESEN
ASTRONOMER

Anders is the man behind the Astro Anecdotes website – who better to regale the oddest tales in pro stargazing. *Page 44*

Welcome

2015 was spectacular in more ways than one

What a year 2015 has been for astronomy. Highlights from these shores included the solar eclipse in March, a Perseid meteor shower unspoilt by the Moon in August and September's total lunar eclipse – and I almost forgot to mention our 10th anniversary in June! Out in space it has been a similarly spectacular story, and on page 66 science consultant for Guinness World Records Dave Hawksett, who has a particular interest in space, takes a look at the missions and discoveries that will make this year one to remember.

Of course, there's one notable event that is yet to come, and that's the planned launch of the UK's first official astronaut, Major Tim Peake, to the ISS on 15 December. This is the latest – and very exciting – chapter in this country's long history of spaceflight and science research, and on page 32, Andrew White, looks at the achievements spearheaded by our astronomers and engineers. And with the calendar you'll find free with this issue, we look forward to the best of next year's observing. There are some promising oppositions, conjunctions and transits to look forward to.

Enjoy the issue and seasons greetings!

Chris Bramley Editor

PS Next issue goes on sale 17 December

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Sky at Night LOTS OF WAYS TO ENJOY THE NIGHT SKY...

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NEW TO ASTRONOMY?
See *The Guide* on page 80 and our online glossary at www.skyatnightmagazine.com/dictionary

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Tim Peake's mission to the ISS is just the latest chapter in the UK's spacefaring history.

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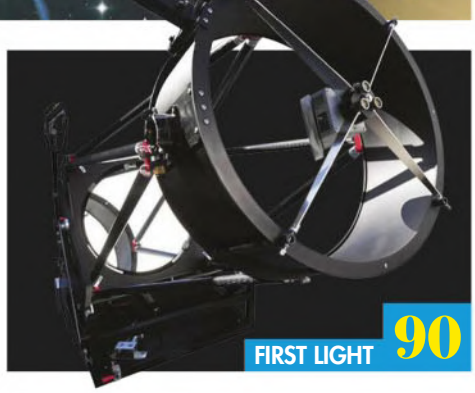

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THE GEMINIDS 2015

The Geminid meteor shower is one of the most spectacular of the year and can be fully enjoyed with the naked eye. In this issue's Bonus Content we talk to astrophysicist Prof Alan Fitzsimmons who explains what the Geminids are and how to observe them. Plus, plan your own observing session and photograph the meteors with our downloadable guides.

EVERY MONTH

VIRTUAL PLANETARIUM

With Paul Abel and Pete Lawrence

Take a tour of December's night-sky highlights with Paul and Pete.

HIGHLIGHTS

THE SKY AT NIGHT

October's episode looks at cosmic volcanoes, from the extinct giants of Mars to the cryovolcanoes on Triton. Geologist Dr Hermione Cockburn compares Earth's volcanoes to those found elsewhere in our Solar System, while Chris and Maggie explore the science behind the eruptions.

INTERVIEW: THE STORY BEHIND STAR MEN

We talk to director Alison Rose and Prof Neville Woolf about their new astronomy documentary film *Star Men*.

HOTSHOTS: TOTAL LUNAR ECLIPSE SPECIAL

Download and view our online gallery of this month's *Hotshots* special on the total lunar eclipse, featuring images sent in by you.

AND MUCH MORE...

- HOTSHOTS GALLERY
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- DEEP-SKY TOUR CHART

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ISSN 1745-9869

Peering beyond the veil

These colourful wisps of gas are all that remain of a star that exploded about 8,000 years ago

HUBBLE SPACE TELESCOPE, 25 SEPTEMBER 2015

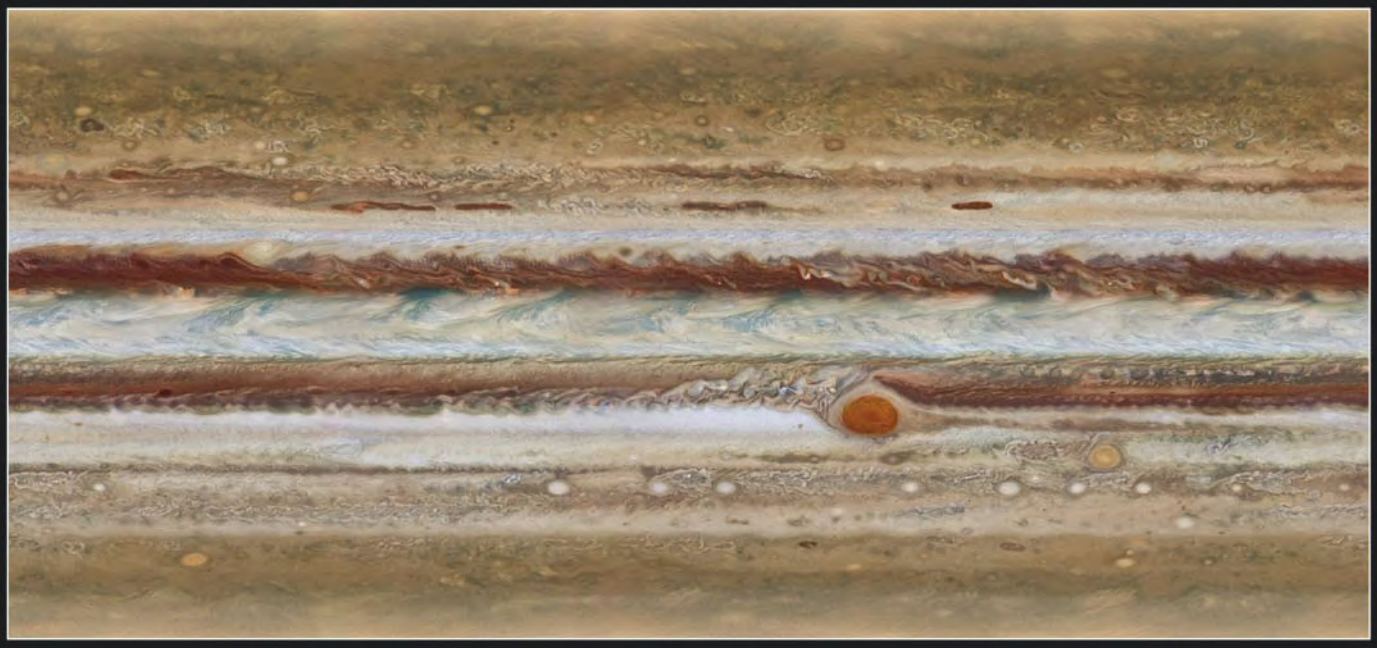
The Veil Nebula is a beautiful example of a supernova remnant, a cosmic structure that formed from the explosion of a massive star. The nebula, the common name of which stems from the fact its delicate filaments look like a piece of colourful material, is about 2,100 lightyears away in the constellation of Cygnus. It is 110 lightyears across, covering an area of six full Moons in the sky as seen from Earth. The Hubble mosaic you see here was constructed out of six images taken by the telescope scanning an area about two lightyears across: just a small proportion of the nebula's massive structure.

The star that formed the Veil Nebula was 20 times more massive than our Sun. Its rippling shape is a result of the blast wave that formed when this stellar giant exploded and blew into a wall of cooler gas. Hubble has captured the phenomenon in intricate detail, not least the array of structures and ripples that illustrate its veil-like structure perfectly. Astronomers are comparing this new image to previous ones captured by Hubble in 1997. In doing so, they can study how much it has expanded over the past 18 years.

YOUR BONUS CONTENT

More stunning space images

NASA/ESA/HUBBLE HERITAGE TEAM



▲ Spot the difference

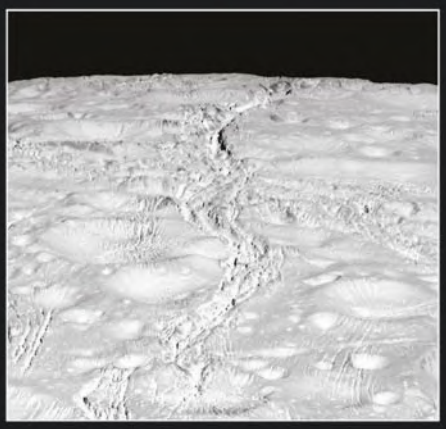
HUBBLE SPACE TELESCOPE, 13 OCTOBER 2015

Jupiter's Great Red Spot – actually a giant storm system – is the most distinctive and recognisable feature on the planet's surface. This Hubble image is one of a series taken over a 10-hour period in order to show the changes in the storm's size and ferocity. At the centre of the spot, a wispy filament can be seen twisting and twirling buffeted by winds blowing at 540km/h.

▲ Cosmic glow

LA SILLA OBSERVATORY, 23 SEPTEMBER 2015

The bright red shades of the Swan Nebula, M17, are the result of glowing hydrogen gas, heated by recently formed blue stars that emit warming ultraviolet light. The white that can be seen in the centre of the nebula is real, not a result of image processing. It is caused by light from the hottest gas at the core mixing with starlight reflected from space dust.



▲ Enceladus's icy impact craters

CASSINI SPACECRAFT, 15 OCTOBER 2015

On 14 October, NASA's Cassini spacecraft made a close flyby of Enceladus, the icy Saturnian moon. In these images, Cassini's camera captured the lunar north pole and its varied, impact-laden terrain from a distance of about 6,000km. By zooming in, scientists have been able to pick out thin cracks crossing over the pole, answering a previous question as to whether these fractures did indeed stretch so far north.

NASA/ESA/A. SIMON (GSFC) M. WONG (UC BERKELEY) AND G. ORTON (JPL-CALTECH), ESO, NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

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Bulletin

The latest astronomy and space news written by **Elizabeth Pearson**

PLUS CUTTING EDGE

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Our experts examine the hottest new astronomy research papers

The Journey to Mars programme has aims beyond the Red Planet; deep space travel is being talked about too

NASA is on a journey TO MARS

It hopes to increase humanity's footprint in deep space

NASA HAS SET out a detailed plan to put a crewed mission on the surface of Mars. In late 2014, the agency announced their 'Journey to Mars' programme, intending to put a human on the surface of the Red Planet by the 2030s; this report sets out how they plan to do so.

NASA plans to work alongside international and industrial partners to create and develop the technology needed to keep humans alive, healthy and working in deep space. Once a crew has landed on Mars, they hope to finally answer the questions about life on the Red Planet and on Earth.

The programme will aim to liberate space travel from its reliance on Earth, allowing autonomous deep space travel. Rather than a singular 'once in a generation' mission, like the Apollo landings, NASA wants to create a platform and infrastructure for deep space exploration, just as the International Space Station is for low-Earth orbit.

Using the ISS, the first phase of the programme will test technologies near Earth, before going further afield to the proving ground of missions to asteroids and the Moon. Finally the agency will begin sending people to missions near Mars and eventually to its surface.

"NASA's Journey to Mars is ongoing right now," says NASA administrator Charles Bolden on the announcement for the plan, "from our Space Launch System rocket and Orion spacecraft to new propulsion and habitation systems – and our partnerships across sectors, across states and across the world make it stronger."

▸ See Comment, right

NASA, ISTOCK

COMMENT

by Chris Lintott

This plan amounts to a list of interesting things that can be done with existing and planned technology, especially the much-maligned Space Launch System, which NASA might well do in the coming decade or so. Rather than being an audacious leap for the stars, it derives from the sad truth that neither the funding nor political will to get us to Mars exists right now.

As a result, a landing sometime in the 2030s – as distant as it has ever been – leaves room for dreaming and speculation. It's a vacuum filled by the Mars One project, with its unfunded and unrealistic plan to send a reality TV cast on a one-way trip. Radical thinking is certainly welcome – the Planetary Society just unveiled a cheap Phobos-first plan to put a crew in orbit – but really the solution is to turn the politicians around. Until there's a clamour to go to Mars that can't be ignored, we're stuck with worthy but uninspiring infrastructure development.

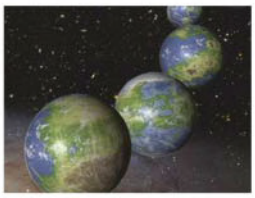
CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF

MOST EARTH LIKE PLANETS YET TO FORM

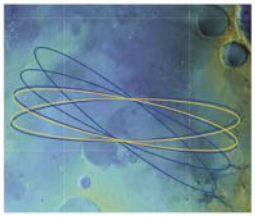
Most Earth-like worlds in the Universe are yet to be born, according to a study of the many worlds found by the Kepler telescope. As many as 92 per cent of Earth-like planets have yet to form, though they will probably not lie in the Milky Way. Our Galaxy has exhausted much of its planet making material, but the potential for another habitable Earth-like planet farther afield looks likely.

"There is enough remaining material after the Big Bang to produce even more planets in the future, in the Milky Way and beyond," says Molly Peeples of the Space Telescope Science Institute.



LANDING SITE FOUND FOR EXOMARS 2018

Oxia Planum, a region near Mars's equator, has been recommended as the landing site for ESA's ExoMars rover in 2018. The location has been selected as a balance between engineering and landing constraints, and the potential scientific return of the mission. ExoMars will launch in May 2018, touching down in January 2019.



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The first science results from Pluto

New Horizons has revealed a world that still hides many mysteries

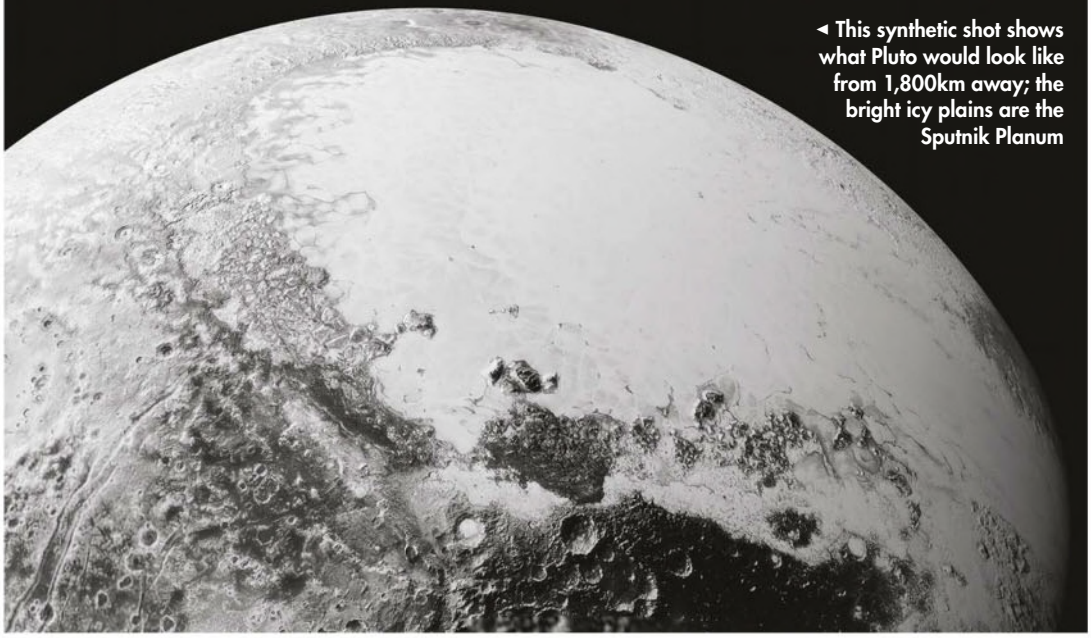
THE FIRST SCIENCE results from the New Horizons probe have been released, three months after the initial flyby. Even from these early findings it appears that the dwarf planet is a highly complex world.

At first glance the tranche of images sent back seem to show mountains and ridges made of nitrogen, carbon monoxide and methane ices, but these are far too weak to support the weight of such large features. Instead it appears that there is a crust of water ice acting as bedrock with a veneer of the more volatile ices on top. Undulations in this bedrock, as large as 150km across, may indicate that it is undergoing some kind of tectonic activity.

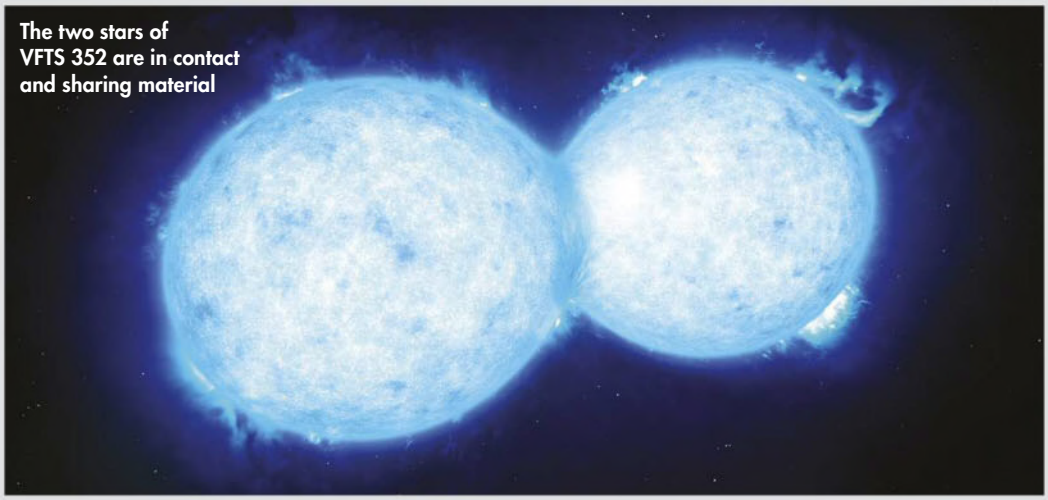
The majority of the surface is a reddy-brown colour, thought to be organic residues called tholins. Tholins are created when nitrogen and methane, both of which are plentiful on Pluto, react with ultraviolet light and charged particles, and only a small amount are needed to create the colours seen on the dwarf planet.

One of the most unexpected regions was the Sputnik Planum, a smooth region devoid of craters and divided into polygonal and ovoid shapes. The cause of these strange shapes is unknown, but they may originate from surface cracking, which could be caused by either contraction or from the underlying rock pushing upwards. To add to the mystery, the region's surface looks to be no more than a few hundred million years old, suggesting some geological activity is replenishing the surface, possibly from surface erosion, crater relaxation or some other method of recycling the crust. However most of these rely on an internal heat source and Pluto is too small to have maintained a molten core on its own, nor does it have the frictional pull of gravity to heat it as the Galilean moon Io does.

"Pluto's diverse surface geology and long-term activity also raise fundamental questions about how it has remained active many billions of years after its formation," says the paper, whose lead author Alan Stern is New Horizon's principal investigator. "This suggests that other small planets of the Kuiper Belt, such as Eris, Makemake and Haumea, could express similarly complex histories that rival those of terrestrial planets."
http://pluto.jhuapl.edu



◂ This synthetic shot shows what Pluto would look like from 1,800km away; the bright icy plains are the Sputnik Planum



The two stars of VFTS 352 are in contact and sharing material

Two stars head for collision

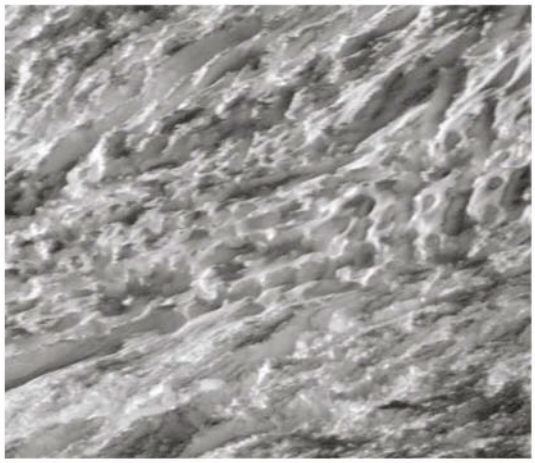
The pair could be headed for a spectacular supernova

TWO STARS HAVE been found close enough together that they touch one another. This double star system, VFTS 352, is located 160,000 lightyears away in the Tarantula Nebula. The stars are only 12 million km apart, creating a bridge of matter between them. It is the most massive of a rare class known as 'overcontact binaries', with a combined mass of about 57 times that of the Sun. The stars are almost identical in size and strong tidal forces mean that the internal material of the two stars is strongly mixed.

"VFTS 352 is the best case yet found for a hot and massive double star that may show this kind of internal mixing," says Leonardo A Almeida of the University of São Paulo, Brazil. "As such it's a fascinating and important discovery."

www.eso.org

▲ The jets of Enceladus, as seen in an unprocessed shot from Cassini's closest ever flyby



▲ During the close flyby, Cassini snapped images of the fast-moving terrain below

CASSINI DIVES INTO ENCELADUS'S PLUMES

THE CASSINI PROBE performed its deepest ever dive through an ice plume of Saturnian moon Enceladus. The dive was only 49km above the surface and took place on 28 October.

When the Cassini mission first approached the moon it discovered the towering plumes of water and organic molecules that spray out of its southern pole. It's thought that they are forced up from a subsurface ocean. The probe used its gas analysing and dust detecting instruments to directly sample material from the moon's plume, allowing researchers an insight into the ocean that would otherwise be inaccessible.

Though the plume dive was not intended to directly look for life on the moon, the data taken during the dive will hopefully shed light on whether life could potentially be lurking under the surface.

"Cassini's stunning images are providing us a quick look at Enceladus from this ultra-close flyby, but some of the most exciting science is yet to come," said Linda Spilker, the mission's project scientist.

www.nasa.gov/cassini

NEWS IN BRIEF

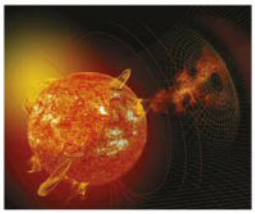
LUNAR MOUND'S VOLCANIC ORIGIN

The Mafic Mound, located in the Moon's South Pole-Aitken Basin, may have formed due to the unique volcanic processes created by the heat of the colossal impact that formed the basin itself. The mound is much richer in calcium than the surrounding rock, suggesting it was drawn up by a volcanic process.

"If the scenarios that we lay out for its formation are correct, it could represent a totally new volcanic process that's never been seen before," says Daniel Moriarty of Brown University.

LARGE SOLAR STORMS DODGE DETECTION

The largest solar storms may slip through current detection methods. Early warning systems that measure magnetic disturbances could miss signs of a potential threat if positive and negative fluctuation cancel each other out. The current system failed to detect a huge flare that occurred in 2003. "One of the conclusions is that the indices commonly used by scientists failed to detect such an important event," says Consuelo Cid of the Universidad de Alcalá.



CUTTING EDGE

Our experts examine the hottest new research

Trial by galaxy

Why recycled dwarf galaxies left over from major mergers support the case for dark matter

NASA/H. FORD (JHU)/G. ILLINGWORTH (UCSC/LO) M.CLAMPIN (STSCI)
G. HARTIG (STSCI) THE ACS SCIENCE TEAM, AND ESA

▲ **A tidal trail flows from the Tadpole Galaxy; this tail could give rise to single stars, whole clusters or even a small dwarf galaxy**

The fact that most of the Universe's matter is in the form of mysterious dark matter – something we don't understand – is embarrassing and fascinating in equal measure. Instinctively, resorting to filling space with a new kind of particle seems desperate, and many of the people I meet when I give talks would prefer an alternative.

For several decades now, that alternative has tended to take the form of theories which muck about with gravity. Make gravity behave differently on the largest of scales, or in the emptiest parts of space, and you might just be able to get rid of the need for dark matter.

What's needed are scenarios that can test these rival ideas, and in a recent paper a team led by Federico Lelli of Case Western University in Cleveland have put them head to head. The challenge is to explain observations of an unusual type of galaxy, formed not in the loneliness of deep space but as the result of a violent merger between two larger systems.

These are the tidal dwarfs, 'recycled' objects that form from the debris of major galaxy mergers. Think of the long streams of stars, gas and dust that stretch away from the centre of famous merging systems like the Antennae Galaxies. If these tidal tails contain enough material, then they can collapse, forming stable, if small, dwarf galaxies with a newly independent existence.

So what? The material that ends up in those tidal tails comes from the discs of the colliding galaxies, and according to the standard theory discs are dominated not by dark matter but by normal, baryonic matter. The dark matter forms a spherical halo within which the disc sits.

If dark matter rules the day, then these galaxies should be a rare exception where what we see – in the form of 'normal' matter – is all we get. If gravity is behaving oddly, there's no reason for it not be odd here too and these galaxies should have something strange going on. So who wins?

The result is a near-knockout in favour of dark matter. Six galaxies were included in the study, and each of them was found to have formed a rotating disc; in other words, they are well on their way to being proper galaxies. The behaviour of these discs, and especially the speed with which they are rotating, was found to be consistent with models in which no dark matter was needed, and hence which provided no opportunity to fiddle with gravity.

> "If gravity is behaving oddly, there is no reason for it not be odd here too"

Indeed, when the rotational speed of the disc was plotted against the observed mass of normal matter – forming an iconic plot called the Tully-Fisher relation – these tidal dwarfs stood apart from other small systems. Further confirmation that these things are odd, and odd in precisely the way you'd expect if they were uniquely dark matter free.

Until we get a good understanding of what dark matter actually is, doubts will remain. Experiments like this one, though, convince me that the most likely explanation is that the Universe is filled with the stuff – whether astronomers like it or not!

CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project.

CHRIS LINTOTT was reading… *Gas dynamics in tidal dwarf galaxies: disc formation at z=0* by F Lelli et al
Read it online at http://arxiv.org/abs/1509.05404

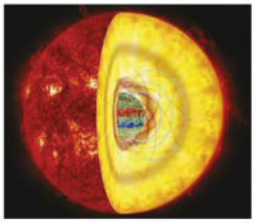
NEWS IN BRIEF

RED GIANTS HAVE MASSIVE MAGNETIC FIELDS

Astronomers have probed the inner magnetic field of dozens of red giant stars using astroseismology – and discovered their internal magnetic fields are over 10 million times stronger than the Earth's.

"In the same way medical ultrasound uses sound waves to image the interior of the human body, asteroseismology uses sound waves generated by turbulence on the surface of stars to probe their inner properties," says Jim Fuller from the California Institute of Technology.

The results could help explain how stars evolve, and how stellar remnants such as white dwarfs and neutron stars have such large magnetic fields.



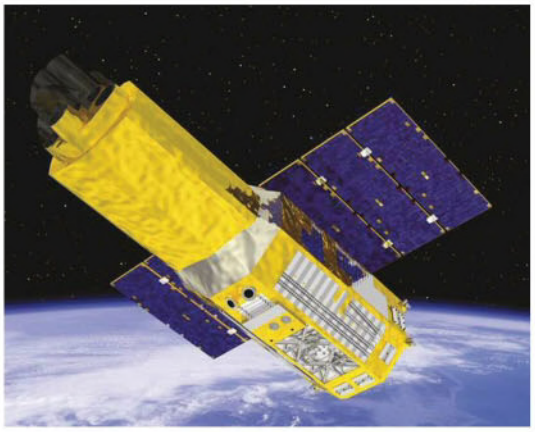
SPACE LAUNCH SYSTEM ON TRACK FOR A JOURNEY TO MARS

NASA's Space Launch System has passed through the critical design review step of development. The vehicle will be the first human rated rocket NASA has developed in almost 40 years, and will form the backbone of its Journey to Mars programme.

RAFAEL A. GARCÍA (CEA) JIM FULLER (CALTECH) GABRIEL PÉREZ (SMM/IAC) KYLE C. AUGUSTSON (HAO) ET NASA AIA/SDO, NASA/MSFC, ISAS/JAXA, MARK A. GARLICK / HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS, NASA/JPL-CALTECH

Universe similar to the Sun

Our Solar System is typical, making finding an analogue likely



▲ **The Japanese satellite Suzaku, launched in 2005, is used to observe X-rays coming from the Universe**

THE CHEMICAL COMPOSITION of the Universe is, on average, the same as that of our Sun. The average chemical makeup of our Universe was measured using the Japanese Aerospace Exploration Agency's Suzaku X-ray satellite. The dust in intergalactic space is hot enough to give off X-rays, allowing astronomers to measure the amount of metals within the gas and dust.

"What we found was that the ratios between the abundances of iron, silicon, sulphur, and magnesium are constant throughout the entire volume of the Virgo Cluster, and indeed roughly consistent with the composition of our own Sun and most of the stars in our Galaxy," explains Dr Norbert Werner from Stanford University.

http://global.jaxa.jp/projects/sat/astro_e2/

WHITE DWARF STAR KILLS ITS PLANETS

A WHITE DWARF star has been spotted in the process of shredding one of its planets. NASA's Kepler space telescope found several chunks of material orbiting around the star which match the characteristics of a planet being torn apart. The total mass is estimated to be around the same as the dwarf planet Ceres in the Asteroid Belt.

The discovery could spell out the cause of 'polluted' white dwarfs, which show traces of heavy metals that should have sunk to the core.

"Now we have a 'smoking gun' linking white dwarf pollution to the destruction of rocky planets," says Andrew Vandenburg of the Harvard-Smithsonian Centre for Astrophysics.

http://kepler.nasa.gov

White dwarf star WD 114+017 seems to be in the process of vaporising a planet in orbit around it

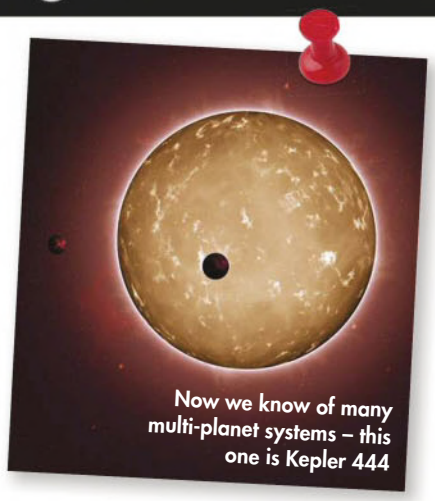
Looking back The Sky at Night

December **1970**

In 1970, the *Sky at Night* team considered the possibility of planets around other stars. It wasn't for another 21 years that the first exoplanet was confirmed. HD 114762 b is at least 10 times the mass of Jupiter and was found by looking for motions in its host star's orbit, caused by the slight pull of the planet's gravity.

Since then thousands of planets have been added to the list. Many worlds that we once thought couldn't possibly exist have been found during the exoplanet hunt, such as hot Jupiters – gas giants so close to their host star it takes a matter of days, or hours, to orbit.

A lot of the focus has been dedicated to searching for habitable worlds where water can exist as a liquid. Though a 'second Earth' has yet to be found, there have been many rocky planets of a similar size and type, and current estimates say that around 20 per cent of stars may be host to a terrestrial planet.



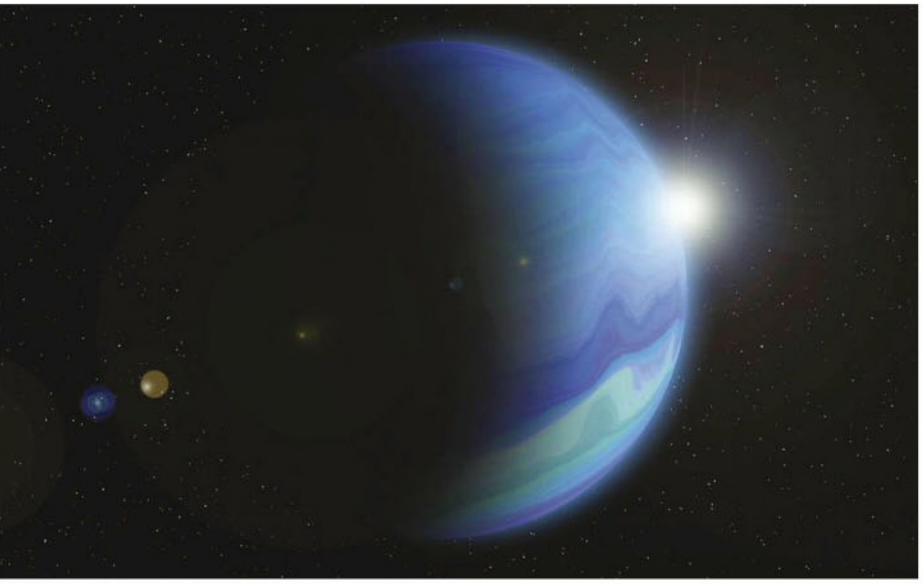
Now we know of many multi-planet systems – this one is Kepler 444

CUTTING EDGE

Our experts examine the hottest new research

Was there once a fifth giant planet in our Solar System?

Saturn or Jupiter may have ejected a sibling ice giant from our neighbourhood long ago



ESA/FOSTER + PARTNERS

▲ **Is there an ice giant like this now wandering through space without a parent star?**

The early history of the Solar System is believed to have been unstable and tumultuous, with strong gravitational interactions between the freshly formed worlds causing the initial orbits of the giant planets to migrate into the architecture of our planetary neighbourhood we see today.

The model that best explains the current configuration of our Solar System is known as the 'Nice model', and neatly accounts for the observed orbits of the four giant planets, the structure of the Kuiper belt, Jupiter's capture of its Trojan asteroids, and the triggering of the Late Heavy Bombardment that is believed to have occurred around four billion years ago. However, there are still a few inconsistencies with it. One proposed solution is that perhaps our Solar System today isn't all that it once was: if in fact there used to be a fifth giant planet, an ice giant like Uranus, that suffered several close encounters with Jupiter and Saturn and was eventually flung into interstellar space, the fit to the observed architecture of the current Solar System is much better.

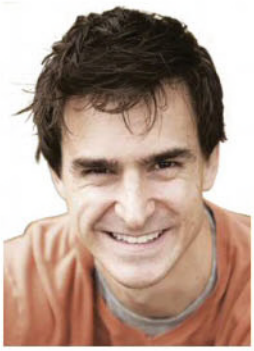
This possibility, where the gas giant planets push one of their siblings right out of the nest, is known as the 'jumping Jupiter scenario'. And indeed, astronomers have discovered a number of free-floating planets, wandering between the stars in our Galaxy. However, any close encounters between the giant planets in the Solar System's tumultuous early history would also have disrupted the orbits of those planet's outer moons. So as Ryan Cloutier and his colleagues at the University of Toronto point out, considering the orbit of Callisto (Jupiter's outermost Galilean moon) and Iapetus (around Saturn) would provide vital information on how closely their parent planets could have approached an extra ice giant.

If the Solar System ever did have a long-lost extra ice giant planet, its gravitational ejection into interstellar space must be consistent with the orbits of the moons we observe today around Jupiter and Saturn. Cloutier and his team therefore simulated various swing-by encounters between Jupiter or Saturn and a hypothetical ice giant planet to see how plausible it was that the ice giant could be ejected from the Solar System whilst still leaving the outermost large moon undisturbed in its orbit.

> "Astronomers have discovered a number of free-floating planets, wandering between the stars"

Some of these simulated close encounters resulted in the ice giant receiving a large velocity kick – just like our deliberate attempts at gravitational slingshots with space probes – and being flung on an escape trajectory. But how many of these left the gas giant planet with a recognisable system of moons? When modelling Saturn, Cloutier and his team found that the orbit of Iapetus is irreconcilably disrupted in 99 per cent of the ejection encounters, leading them to conclude that if we ever did have another ice giant planet in our solar family, it almost certainly wasn't Saturn that banished it.

But for Jupiter, around half of the ejection encounters preserve Callisto in its orbit. Cloutier is quick to point out, though, that this doesn't necessarily mean that there was an extra planet that became ejected, just that Callisto's orbit turns out to not offer a very tight constraint on the plausibility of the fifth giant planet hypothesis.



LEWIS DARTNELL is an astrobiologist at the University of Leicester and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

LEWIS DARTNELL was reading… *Could Jupiter or Saturn have ejected a fifth giant planet?* by Ryan Cloutier, Daniel Tamayo, Diana Valencia
Read it online at http://arxiv.org/abs/1509.05397

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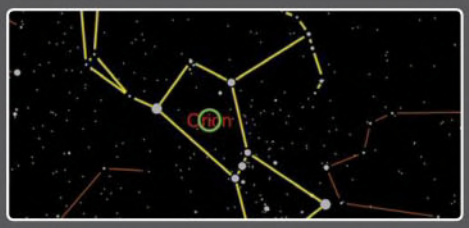

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What's on

Our pick of the best events from around the UK

Explore the Universe in 360°

Glasgow Science Centre, throughout December

▲ Steve Owens welcomes audiences to Glasgow's full dome digital planetarium

Astronomer and author Steve Owens is the new manager of Scotland's first full-dome digital planetarium, which opened in September this year at the Glasgow Science Centre. A recent £450,000 upgrade offers even deeper exploration of the Universe, with 360° films and live astronomy shows.

Owens says: "The new digital system has transformed our planetarium, allowing us to take our audience to the edge of the known Universe, to planets around alien stars and to anywhere in our Solar System. This will be the first time Scotland's planetarium audiences will be able to fly through the rings of Saturn, see Pluto up close and land on Mars. Plus, the star show content can be immediately updated, allowing our expert presenters to react to each new scientific discovery."

The Space Explorers show (for those aged seven and under) runs on Saturdays and Sundays throughout December and daily from the 21st-24th and 28th-31st at 11.20am and 3.20pm.

Wonders of the Night Sky (for those aged seven and over) runs Wednesday to Friday from the 2nd-18th at 2pm; Monday to Wednesday from the 21st-30th at 12pm and 4pm; Thursday 24th and 31st at 12pm; and Saturdays and Sundays at 12pm and 4pm.

Full-dome films We Are Aliens and Back to the Moon for Good, featuring the voices of Rupert Grint and Tim Allen, run Saturdays and Sundays throughout December and daily from the 21st-24th and 28th-31st at 10.40am and 2.40pm.

Planetarium tickets are £2.50 on top of Science Mall tickets, which are £10.50 for adults and £8.50 for children/concessions

www.glasgowsciencecentre.org

BEHIND THE SCENES

SKY AT NIGHT CHRISTMAS SPECIAL 2015

BBC Four, **27 December,** time and repeat broadcast TBC*

The identity of the star of Bethlehem has eluded astronomers – if it even existed

THE STAR OF BETHLEHEM

Astronomers have been fascinated by the Star of the Bethlehem for centuries. Johannes Kepler was convinced it was a supernova; others have suggested a comet, meteor or even a planetary conjunction. This month the team mount an investigation, using historical evidence to reconstruct events in the night sky 2,000 years ago.

Check www.bbc.co.uk/skyatnight for subsequent repeat times

GLASGOW SCIENCE CENTRE, JAMIE GILMOUR, JOHN DAVIES, ISTOCK X 2

Meteorites and the Early Solar System

Macclesfield Astronomical Society, Village Hall, Goostrey, 15 December, 8pm

Many meteorites are fragments of asteroids, the leftovers of planet formation. Prof Jamie Gilmour of the University of Manchester (pictured) gives a brief introduction to the topic and reveals what meteorites are teaching us about the prehistory and formation of our Solar System. Entry is free.

www.maccastro.com

New Horizons in the Solar System

Astronomical Society of Edinburgh, Augustine United Church, Edinburgh, 4 December, 8pm

Dr John Davies of the Royal Observatory Edinburgh (pictured) hosts a lecture on recent robotic missions to Solar System bodies, focusing on Dawn's orbit of the dwarf planet Ceres; Rosetta and the Philae lander's observations of comet 67P; and New Horizons' journey to Pluto and its moon Charon.

www.astronomyedinburgh.org

Newton Rules!

William Herschel Society, Bath Royal Literary and Scientific Institution, Queen Square, Bath, 4 December, 7pm

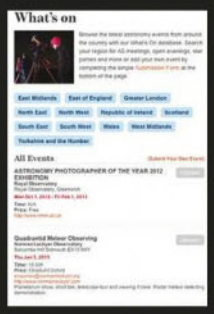
There is an impression in popular science that Einstein's theory of general relativity has superseded Newton's law of universal gravitation. Dr Roger Moses of the University of Bristol argues that this is not the case, and that Isaac Newton still rules. The talk is £2 for members and students, £4 for visitors.

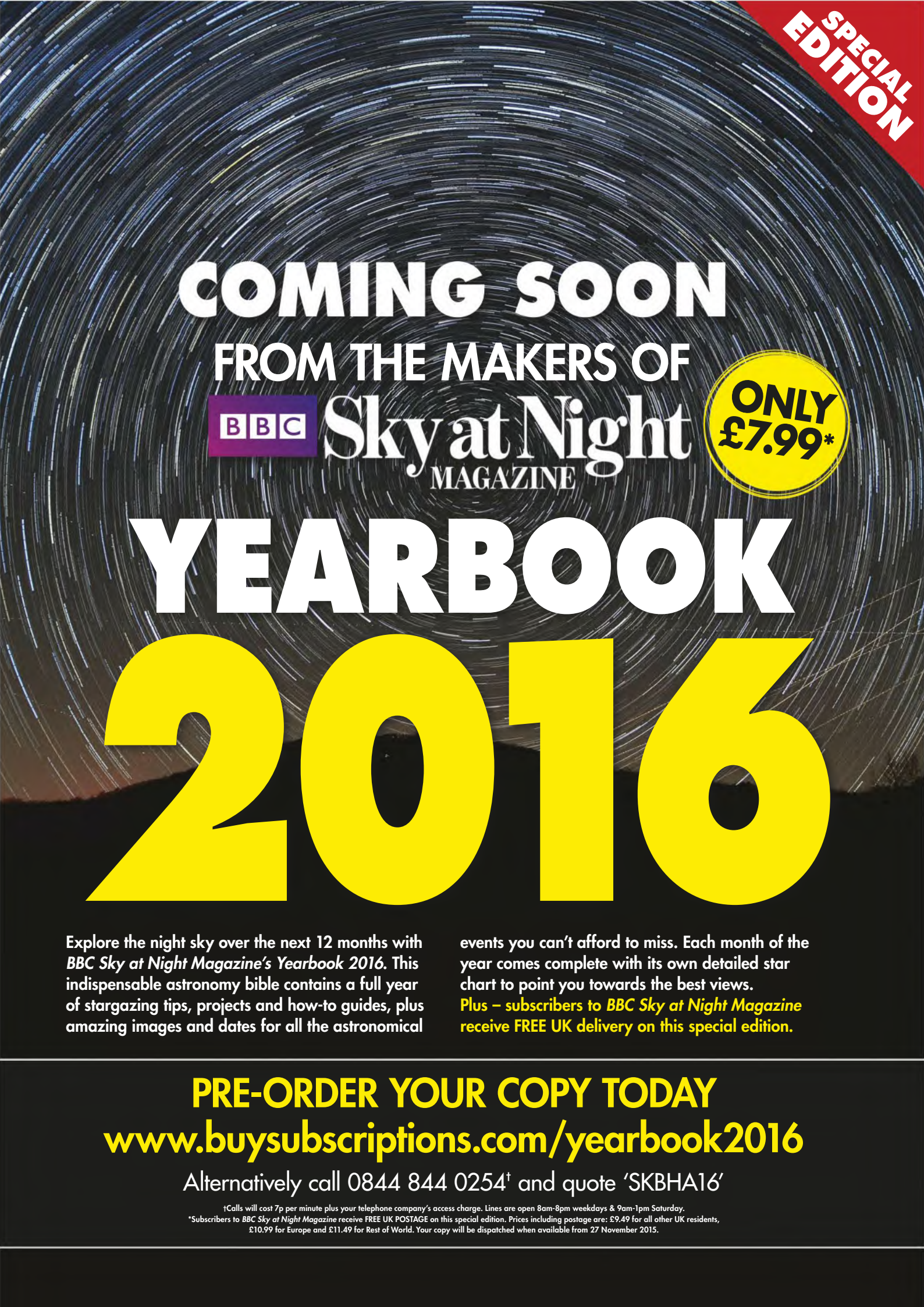
www.williamherschel.org.uk

MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.

To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the page.





Explore the night sky over the next 12 months with *BBC Sky at Night Magazine's Yearbook 2016*. This indispensable astronomy bible contains a full year of stargazing tips, projects and how-to guides, plus amazing images and dates for all the astronomical events you can't afford to miss. Each month of the year comes complete with its own detailed star chart to point you towards the best views.

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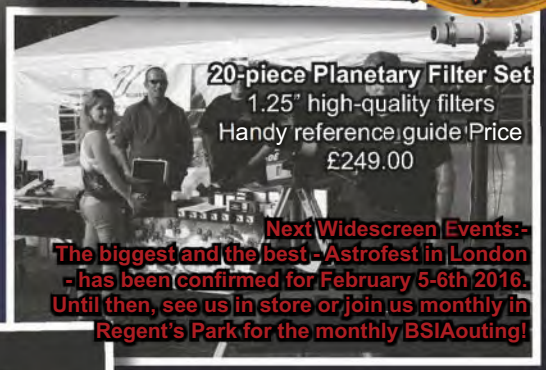

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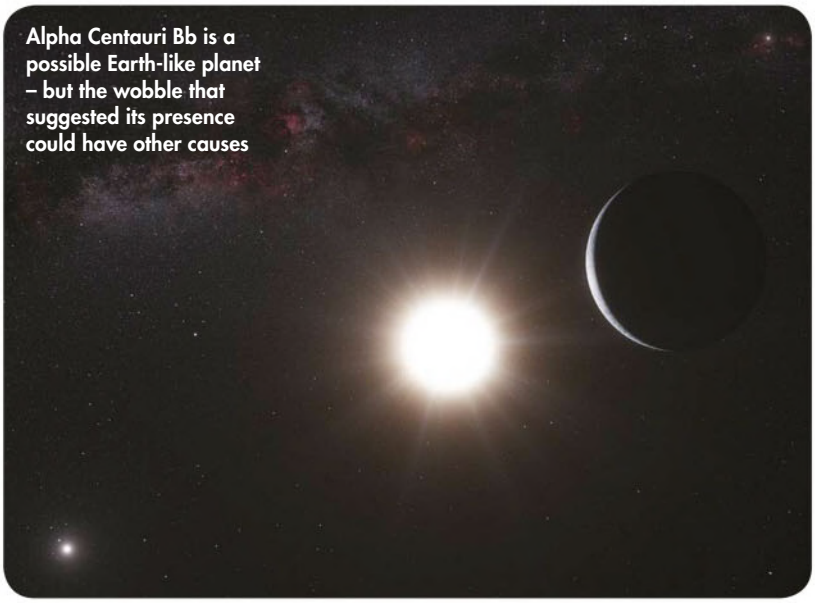
A PASSION FOR SPACE

with **Maggie Aderin-Pocock**

The Sky at Night presenter looks back on the menagerie of exoplanets out in the cosmos



Alpha Centauri Bb is a possible Earth-like planet – but the wobble that suggested its presence could have other causes

ESO/L. CALÇADA/NICK RISINGER

Over the past 20 years or so exoplanets have been transforming our understanding of what a planet and even a star system can be. The very first exoplanet was found in 1991, but since then many thousands have been detected; there are around 1,900 confirmed exoplanets out there to date. In the past we considered our Solar System fairly unique, with multiple planets going around a star, but now we are very much aware that this seems to be the norm and most of the stars we look at seem to have planets in orbit around them. Current estimates suggest that one in five Sun-like stars have an Earth-sized planet in orbit.

The types of planets that we have discovered have been bewildering. There are super-Jupiters, rocky giants, mini-Neptunes and gas dwarfs, and that's before getting to the Earth-like, Earth-sized and the super-Earths out there.

But detection and confirmation of the presence of an exoplanet is challenging. The first planets detected were found using the radial velocity method. This involves measuring the wobble of a star that is caused by the movement of a planet in orbit about it, a movement that is miniscule and very hard to detect. As a result, the first exoplanets detected were Jupiter-sized or bigger, since they exerted the greatest movement on the star being observed.

Transit triumphs

There are now other detection methods, one of the most popular being the transit technique, which registers a dip in a star's brightness as a planet travels in front of it. The transit method gives us information about a planet's orbit and size. The radial velocity method gives us information about the planet's mass, so by combining the methodologies much information can be interpolated about the planets and this gives us the large list of planet types above.

However, these methods aren't foolproof and even NASA's Kepler Space Telescope, which has detected around 1,000 of the confirmed exoplanets found to date, has found many thousands more candidates, 11 per cent of which will be false positives. A case that highlights the point is the detection of Alpha Centauri Bb. Using the radial velocity method, a tiny wobble in this star's motion was attributed to the presence of a rocky, Earth-sized world sitting at an amazingly close distance to the star (around one-tenth of the orbital distance of Mercury). But other observations have found the signature movement to be transitory. Models suggest it could be due to sunspot activity or the gravitational pull of another star. The jury is still out on this one but it shows how difficult the detections can be.

The future looks bright for exoplanet detection. Kepler continues to do sterling work and has been joined by ESA's Gaia mission, which is also designed to find larger exoplanets. In the future we will have the James Webb Space Telescope joining the hunt and TESS, which will be looking for smaller, more Earth-Like planets but could detect planets that we cannot even envisage today.

Maggie Aderin-Pocock is a space scientist and co-presenter of *The Sky at Night*

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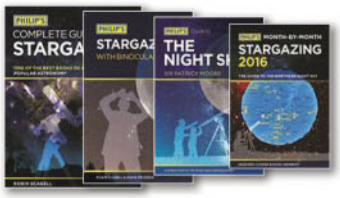
This month's top prize: four Philip's books

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philips: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Robin Scagell and David Frydman's *Stargazing with Binoculars* and Heather Couper and Nigel Henbest's *Stargazing 2016*

PHILIP'S



SOCIAL MEDIA

WHAT YOU'VE BEEN SAYING ON TWITTER AND FACEBOOK

Have your say at **twitter.com/skyatnightmag** and **facebook.com/skyatnightmagazine**

@skyatnightmag asked: Do you just look out the window to see if it'll be a clear night, or do you have a reliable forecasting method?

@c2seven If it's a full moon it'll be clear #astrophotographerscurse

Dave Thompson Metoffice IR satellite chart

@chongsparks if my knee & elbow ache more than normal it'll be cloudy/rainy. Very scientific method.

@JP_Astronomy Scope Nights, Accuweather and MetCheck are the methods I use... Usually spot on

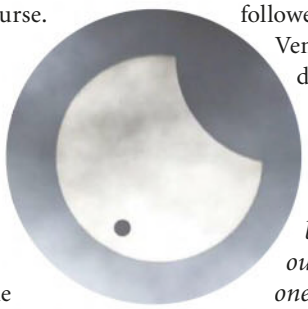
Alan Bickerstaff A weather forecasting stone serves well as is as good as most mainstream forecasts ;)

MESSAGE OF THE MONTH

TV writers need to get their facts straight

I enjoyed your article 'The Science of Fiction' in the October issue, about educating science-fiction writers in real science. It made me think, though, that it's not just science fiction writers that would benefit from this course. TV script writers also get their science wrong, with some pretty entertaining results. I was reminded of recent crime drama in which the plot revolved around a village that was seemingly inhabited entirely by amateur astronomers who were being killed off at an alarming rate. When questioned as to his whereabouts on the night of a murder, a potential suspect replied that there had been a transit of Venus that night and he had spent all night in the observatory. This raised a few eyebrows in our house. Furthermore, the episode began with all the village astronomers observing a total eclipse of the Sun. A total eclipse visible from England followed within a few hours by a transit of Venus – pure fantasy? Maybe our descendants will enjoy such an astronomical feast.

Dale Taylor, Worcestershire



▲ **An eclipse and a transit together? The odds are... astronomical**

Spotting slips like this is one of the banes (or should that be benefits) of our hobby, Dale! Who knows, perhaps one of our readers will calculate how long it'll be until there's a transit of Venus and a total solar eclipse within hours of each other. ***– Ed***

A reversed eclipse

▲ **If you could stand on the Moon, you would see that Earth has a halo**

During the lunar eclipse in September 2015, the Moon looked red as viewed from the Earth. If one were standing on the Moon watching the eclipse, what would you see? Obviously you'd see a dark circle (rather larger than the sun's apparent size) moving across the face of the Sun, but where does the red colour come from? I presume that, at totality, you'd see an intense Earth-sized reddish circle hovering in the sky, as the sunlight refracts through the Earth's atmosphere? But the Earth's atmosphere is only a few kilometres thick – a dimension impossible to see at 400,000km distance – so for the Moon to be bathed in enough light for us to see the red colour back on Earth, would the 'Earth halo' as seen from the Moon have to be extremely intense?

Graham Holmes, Ipswich

Though Earth's atmosphere is extremely thin, it's enough to create a narrow cone of reddened light and if you were standing in this umbral region on the Moon you would indeed see a glowing red ring. It would be quite a sight! ***– Ed***

Moons everywhere

Thank you for the helpful chart of the 'wandering stars' and Moon in the October issue. Having reached the age when loo-trips punctuate the night, it has been superb to see the sights in the east. Perfectly dark-adapted eyes and minimal light pollution in the wee small hours permit immediate observations. Turning to the article 'The Science of Fiction' in the same issue John Gilbey makes a confession. "I'd referred to the Moon as a planet – I was saved from ignominy an alert copy editor." At a public observing session run by our society we were observing Jupiter. I asked a lad how many moons he could see. "Three," he replied, "But there should be four." I asked where the missing one could be. He swung round and pointed to our Moon.

Dermot Stewart, South East Kent Astronomy Society, Canterbury

The educational service provided at public observing sessions is immense, Dermot. Glad to have repaid the service in small part through the magazine. ***– Ed***

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Sky at Night MAGAZINE

YOUR BONUS CONTENT A gallery containing these and more of your stunning images

Hotshots

LUNAR ECLIPSE SPECIAL

Early on the morning of 28 September, a total lunar eclipse appeared in the skies above the UK and beyond. Here we present the best of your images capturing the beauty of this rare event

PHOTO OF THE MONTH

▲ Ralph Smyth, Lisburn, County Antrim

Ralph says: "The weather leading up to the start of the eclipse was worryingly cloudy, but I was determined to stay up and capture as much of it as possible. Fortunately the weather cleared and I captured a sequence of images that I assembled into this montage, deliberately making the image around mid-totality a little larger than the others. The Moon was a lovely bright copper colour at this point. I am pleased with the images and feel very fortunate to have been able to record this beautiful event."

Equipment: Canon EOS 1000D DSLR camera, Sky-Watcher Evostar ED80 Pro refractor, Sky-Watcher HEQ5 Pro SynScan mount.

***BBC Sky at Night Magazine* says:** "The effort and skill involved in assembling the montage is quite a feat, but Ralph has also managed to capture each part of the sequence in amazing detail, providing a crisp, clear and beautiful depiction of the eclipse from start to finish. This is one of those astro images that is both stunning and astronomically interesting."

About Ralph: "After owning and observing with a few telescopes for a number of years, I was inspired by the work of others to begin imaging in 2005. Initially I used a modified webcam but now have a dedicated planetary camera and a modified DSLR. I like to image the Moon and planets, but have recently begun to photograph some deep-sky objects."

Houssem Ksontini, Tunisia ▶

Houssem says: "I took the image in Ain Zaghouan near Tunis from 1.05am to 2.50am. I received my telescope three months ago and this my first eclipse, so I tried to enjoy it and do my best. As the luminosity of the Moon changes continuously during an eclipse, the main difficulty was to be careful when changing the exposure time to not overexpose it."

Equipment: Nikon D3000 DSLR camera, Sky-Watcher N 150/750 Explorer Newtonian reflector, Sky-Watcher NEQ3-2 mount.

◀ James Robertson, Somerset

James says: "This was captured on holiday in Somerset through the night. The changing lunar brightness meant I had to take many shots to get one right exposure and not having a tripod, the camera rested on a ledge poking out of an upstairs window!"

Equipment: Sony α3000 DSLR camera, Zuiko 35mm lens, Olympus Zuiko 75-150mm zoom lens.

◀ Keith Bramley, Pilling, Lancashire

Keith says: "This was taken from my back garden using my home-made pier setup. I imaged up to totality every four minutes and found I had to adjust the exposure quite drastically close to totality to get any detail."

Equipment: Canon EOS 450D DSLR camera, Sky-Watcher MN190/1000 Maksutov-Newtonian.

▼ Jamie Cooper, Northamptonshire

Jamie says: "I had not seen a total lunar eclipse under clear skies for more than seven years so I was looking forward to this one. Thankfully the skies stayed clear for the duration. Any tiredness soon drained away as adrenaline coursed through my veins! A great night and well worth the sleep deprivation."

Equipment: Canon EOS 5D Mk III DSLR camera, 4-inch refractor, Sky-Watcher EQ5 mount, 1.4x extender.

Mark Griffith, Swindon ▶

Mark says: "The rare event made for a good imaging opportunity and I got a fantastic view due to excellent visibility and no clouds. I took a set of images every 10 minutes and chose the best nine. This left plenty of time to enjoy the spectacle. I thought I was going to struggle with tiredness but the excitement of the event kept me going until 5.20am with no sleep."

Equipment: Atik 320E colour CCD camera, Sky-Watcher Equinox 3-inch apo refractor, Sky-Watcher NEQ6 PRO SynScan mount.

▲ Alex Shute, Butser Hill, Hampshire

Alex says: "The night was excellent: cold and clear with unobstructed views. I did battle with the dew, but caught around 100 frames with which to create this montage. It was my first attempt at an eclipse and the learning curve made it worthwhile."

Equipment: Modified Canon EOS 1000D DSLR camera, 134mm Canon lens, Sky-Watcher Star Adventurer mount.

◀ Christian Garcia, Spain

Christian says: "The challenge of the photo was to capture the stars and Moon as part of the image. To achieve this, I had to adjust the exposure as it was getting dark. It was a very beautiful eclipse and I'm pleased I was able to get such a good quality photo to remember it."

Equipment: Canon EOS 5D DSLR camera, Teleskop Service 4.5-inch triplet apo refractor, Sky-Watcher NEQ6 mount.

BRITAIN IN SPACE

Tim Peake's planned launch to the ISS in December is the latest chapter in the UK's long history of spaceflight and research into space science, says **Andrew White**

Tim Peake's journey to the International Space Station on 15 December 2015 will make him the eighth Briton in space since Helen Sharman in 1991. But the UK's history in spaceflight and space science goes back long before that.

As with the US and the USSR, Britain's interest in space began after World War 2 and was primarily military, with much of the rocket technology and expertise coming from former German scientists performing tests on captured V2 rockets. Britain's official space programme began in 1952 with the development of rocket launching systems and, in 1959, Britain's first satellite programme started with the Ariel series of satellites.

Under a joint agreement with the US, NASA would provide the rocket and build the satellite – called Ariel 1 – and the experiments on board would be developed by the Science Research Council, the UK's agency for space research at the time. In all, six scientific instruments were supplied by the UK, designed to investigate the relationship between the ionosphere, and cosmic and solar rays.

The successful launch from Cape Canaveral on 26 April 1962 made the UK the third country to operate a satellite. Ariel 1 performed perfectly until 9 July when it, along with one-third of all satellites in low-Earth orbit, was affected by radiation from the detonation of a US Air Force high-altitude nuclear test. The little satellite had kickstarted the UK space sector, and after the US-built satellite Ariel 2 launched in 1964, the stage was set for the first satellite designed and constructed in the UK: Ariel 3. With five experiments, designed to measure the oxygen found at high altitude and study the ionosphere, Ariel 3 was launched on 5 May 1967, and operated well until it was switched off in September 1969.

The next logical step

The UK had now designed and built a satellite, and launched it on an American rocket: the logical next step was for the nation to develop its own launch platform – and this was Black Arrow. The UK had

▲ **The launch of Britain's first satellite, Ariel 1, took place in April 1962, carried by a US rocket; the satellite was built in America too, but its instruments were made by British universities**

▲ **Prospero launches into orbit on a Black Arrow, an evolution of the Black Knight design**

▲ **Black Arrow rockets, the UK's first launch platform, at High Down on the Isle of Wight**

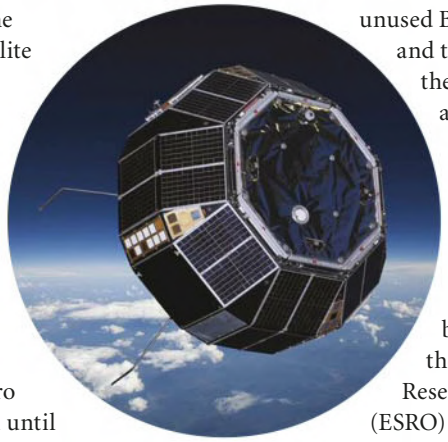
already been working on a platform, called Blue Streak, for its independent nuclear deterrent programme. As part of that, a test programme called Black Knight was started in 1955 to test the effects of high-speed atmospheric re-entry on a rocket. This was the UK's first indigenous rocket programme. Built by the engineering firm Saunders-Roe, the rocket's engines were tested at the remote High Down site on the Isle of Wight, within sight of the famous Needles lighthouse, but the actual launch site was some 15,000km away in Woomera, South Australia.

Between 7 September 1958 and 25 November 1965, 22 Black Knights were launched. But whilst the Black Knight project was gaining valuable data, the UK Government had decided the costs associated with developing its own missile programme had become too much. In April 1960, the Blue Streak programme was cancelled. But in order to justify the large investment, the Government stated its intention to develop a vehicle as a satellite launcher, and Black Arrow was the result.

The first launch, on 28 June 1969, was destroyed by ground control after a guidance system problem caused the rocket to fall to Earth a minute after take-off. The second vehicle launched successfully in March 1970, but another failure followed in September that year. By now, the cost of the programme was causing concern and after the Ministry of Defence decided it would be cheaper to use the US Scout rocket for future launches, the writing was on the wall for Black Arrow: the project was cancelled in July 1971. However, a fourth rocket had already been shipped to Woomera for launch, and the go-ahead was given for launch.

Long-lived Propsero

So it was that on 28 October 1971 – almost as an afterthought – the UK became the sixth country in the world to launch a satellite into orbit on its own rocket. The satellite was called Prospero, and was built by the Royal Aircraft Establishment in Farnborough to test equipment for future satellites, including solar cells and telemetry. Prospero remained in operation until 1973, after which it was contacted annually until 1996. It is still in orbit today; plans to make contact with it for its 40th anniversary in 2011 didn't come to fruition.



▲ **Launched in 1971, Prospero is thought to still be in Earth orbit to this day**

With the cancellation of its indigenous rocket programme, the UK was left with a stockpile of unused Blue Streak sections, and these went into the development of a launch vehicle as part of the European Launcher Development Organisation (ELDO). In 1975 this collaborative body, together with the European Space Research Organisation (ESRO) – a space science research group, merged to form ESA, with the UK as one of the founder members. ▸

BRITONS IN SPACE

Tim Peake will join a list of seven British-born men and women to have flown to space

HELEN SHARMAN

Born: Sheffield, South Yorkshire

First spaceflight: Soyuz TM-12, 18 May 1991

Sharman was the first Briton in space and the first woman to visit Mir as part of Project Juno, a consortium of British companies to privately fund the collaboration with the Soviet Union.

MICHAEL FOALE

Born: Louth, Lincolnshire

First spaceflight: STS-45, 24 March 1992

Thanks to his dual UK/US citizenship, Foale holds the record for the most time spent in space by a Briton – over 374 days, as well as six Space Shuttle missions and stays on Mir and the ISS.

MARK SHUTTLEWORTH

Born: Welkom, South Africa

First spaceflight: Soyuz TM-34, 25 April 2002

With his joint UK/South African nationality, Shuttleworth makes this list with his trip as a space tourist to the ISS – paying around $20 million for the voyage.

PIERS SELLERS

Born: Crowborough, Sussex

First spaceflight: STS-112, 7 October 2002

A veteran of three Shuttle missions, his first was on Atlantis as part of an ISS assembly mission, in which Sellers performed a spacewalk on flight-day four.

NICHOLAS PATRICK

Born: Saltburn-by-the-Sea, Redcar and Cleveland

First spaceflight: STS-116, 9 December 2006

Patrick logged over 308 hours in space on Shuttle missions STS-116 and STS-130. During his first mission the P5 truss segment was added to the ISS.

GREGORY H JOHNSON

Born: South Ruislip, Middlesex

First spaceflight: 11 March 2008

Johnson was the pilot of the 25th Shuttle/ISS assembly mission on board Endeavour, and was also the primary operator of both the Shuttle and the ISS's robotic arm.

RICHARD GARRIOTT

Born: Cambridge, Cambridgeshire

First spaceflight: Soyuz TMA-13, 12 October 2008

The son of NASA astronaut Owen Garriott became a self-funded private astronaut on board a Soyuz to the ISS, where he undertook several education outreach projects.

▸ Meanwhile, the Ariel programme continued until 1979, and the first in the family of military communications satellites called Skynet, built for the UK Ministry of Defence, was launched in 1969. As part of this project, Marconi Space and Defence Systems in Portsmouth built the first communications satellites outside the USSR and US: the two satellites of the Skynet 2 programme.

Joining forces

From the 1970s onwards, collaboration became key and the skills and technology of the UK space programme were much in demand. The first fruit of this was the launch of the fourth and final Orbiting Astronomical Observatory (OAO) satellites in 1972. The previous three probes had been NASA projects, but the fourth, named OAO-3 Copernicus, was a joint venture with the UK's Science Research Council and featured an X-ray detector built by Mullard Space Science Laboratory. Copernicus proved to be the most successful of the four, deeply increasing our understanding of pulsars and other bright X-ray binaries. Then, in 1978, the International Ultraviolet Explorer launched. It was a mission originally proposed in 1964 by British astronomer Robert Wilson, and ultimately became a collaboration between NASA, ESA and the Science Research Council. Designed to last three years, the International Ultraviolet Explorer lasted more than 18 years and was the first space observatory to allow real-time observations.

In 1983, the UK joined forces with the US and the Netherlands to launch the first space-based observatory capable of performing a survey of the entire sky at infrared wavelengths – the aptly named Infrared Astronomical Satellite (IRAS). During its 10-month life more than 250,000 infrared sources were observed and IRAS paved the way for the current generation of infrared telescopes, such as the Wide-field Infrared Survey Explorer (WISE) in 2009.

Away from the government-funded programmes, the UK has become a leader in the commercial spaceflight sector. A sign of this was the SNAP-1 mission launched in June 2000. Created as a test-bed for new micro-technologies, this was the world's first nanosatellite in space to be fully stabilised in three axes. Weighing only 6.5kg, it was funded entirely by Surrey Satellite Technology Ltd (SSTL) which ran the mission jointly with the University of Surrey's Surrey

BRITISH SPACE SCIENCE

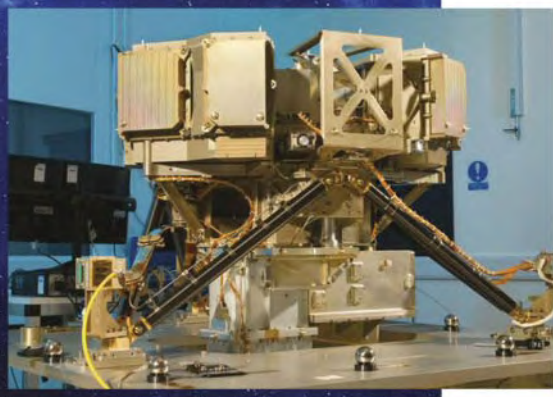
The UK plays a key part in engineering many of the critical components for international space missions

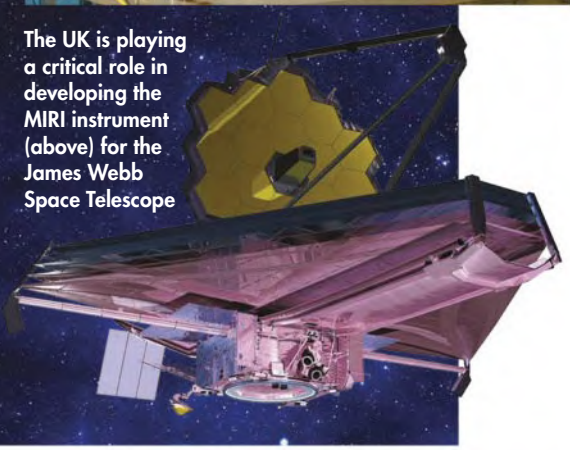
Despite not having as publicly visible a space programme as the US or Russia, the UK has played a major part in building the main components for many space science missions – and it all started with the six instruments designed and built by British scientists for the Ariel 1 satellite in 1962. Four of these were devised by University College London under the leadership of British space pioneer Prof Harrie Massey.

The UK led the consortium that developed and operated SPIRE, the far-infrared camera on board the Herschel Space Observatory, which operated between 2009 and 2013. SPIRE allowed images to be taken at wavelengths never before attempted from space, and is transforming our understanding of the process of star formation. The camera for the High Frequency Instrument on Herschel's sister mission Planck was designed and built by Cardiff University, and has identified over 15,000 new objects at the fringes of our Galaxy.

As well as Tim Peake, Britain has another reason to be watching space in December, with the planned launch of the ESA's Lisa Pathfinder probe from French Guiana on the 2nd of the month. The mission will test the concept of inflight low-frequency gravitational wave detection, which could open up black holes to a new level of scientific investigation – and it is led industrially by Airbus Defence & Space Stevenage.

The UK is also central to the James Webb Space Telescope, the successor to the Hubble Space Telescope that is due to launch in 2018. With a primary mirror over twice the diameter of the Hubble's, the JWST will be more than 400 times more sensitive than current infrared telescopes. The UK's Astronomy Technology Centre in Edinburgh is leading the European team on the Mid Infrared Instrument (MIRI), with the Mullard Space Science Laboratory supplying the telescope's Near Infrared Spectograph's onboard and ground calibration systems.





The UK is playing a critical role in developing the MIRI instrument (above) for the James Webb Space Telescope

Space Centre (SSC). This joint venture led to an innovative project – the STRaND-1 satellite. Launched from India in 2013, this is the world's first smartphone-operated space satellite, running from a Google Nexus One phone – it promises to open up a new level of cheaper satellites.

One of the most important involvements the UK has in space is the DMC – the Disaster Monitoring Constellation – a network of satellites designed to provide detailed images of any part of the world in times of emergencies. DMC images have been used following earthquakes in South America, Hurricane Katrina and even floods in the UK. The current constellation was built by SSTL and is operated for the Algerian, Nigerian, Turkish, Chinese and British governments. Couple this with Beagle 2 – the first European probe to successfully land on Mars – and the development of the Skylon spaceplane by Reaction Engines, and it's easy to see how the UK's space industry employs around 37,000 people directly and generates almost £12 billion a year.

But one aspect of space has historically been missing from the UK's space programme – manned spaceflight. For many years, the UK ▸

The Disaster Monitoring Constellation was used to keep track of flooding in the wake of Hurricane Katrina in 2005

NASA X 6, ISTOCK, NORTHROP GRUMMAN, RAL, ©NASRDA

▲ Tim Peake prepares for his mission to the ISS in December at NASA's Johnson Space Center

▸ had an on-off relationship with government funding for space; in 2009 it was the second wealthiest nation within ESA, yet only its fourth-largest contributor and it did not start funding the International Space Station until 2011. So the announcement in May 2009 of Tim Peake's selection for ESA's Astronaut Corps was a surprise to many.

The creation of the UK Space Agency in 2010 saw part of its £240 million budget directed towards manned research programmes. In 2012, the UK committed £12 million to ESA's microgravity research initiative on the ISS and a one-off £16 million to the propulsion unit for NASA's new manned Orion capsule – designed for transportation to the ISS and beyond. This was a landmark moment: "The UK is on the space station. It's a historic moment," said ESA director-general Jean Jacques Dordain.

And so we arrive at May 2013, and the news that Peake would undertake a six-month mission to the ISS launching late in 2015 – becoming Britain's first official, government-funded astronaut. During his mission, Principia, he will perform more than 30 experiments for ESA and take part in a dozen research programmes for other organisations. But perhaps Principia's most lasting legacy will be Peake's determination to be an ambassador for science and space-based careers – which could provide the UK with the next generation of talent and expertise to push the British space programme far into the future.

ABOUT THE WRITER

Andrew White is a keen amateur astronomer. He's also a writer, film-maker and broadcaster who specialises in wildlife and walking.

SPACE IN BRITAIN

The UK space industry is spread across several key locations in Britain

1 UK ASTRONOMY TECHNOLOGY CENTRE, EDINBURGH
Based at the Royal Observatory on Blackford Hill in Edinburgh, the UK ATC designs and builds instruments for major telescopes and coordinates many joint UK-international projects.
www.ukatc.stfc.ac.uk

2 SPADEADAM, CUMBRIA
Opened in 1957, the Spadeadam Rocket Establishment was the nerve centre of the Blue Streak programme, and was later used by European Launcher Development Organisation, a forerunner to ESA. It is now an RAF training base.
www.raf.mod.uk/rafspadeadam

3 JODRELL BANK OBSERVATORY, CHESHIRE
The observatory is a collection of radio telescopes, the most famous being the 76m Lovell Telescope, the third largest steerable radio telescope in the world. The visitor centre is well worth a trip.
www.jodrellbank.net

4 RUTHERFORD APPLETON LABORATORY, OXFORDSHIRE
RAL plays a major part in both building and testing components for satellites, and receiving and analysing the data collected by spacecraft. There are regular open days.
www.stfc.ac.uk/about-us/rutherford-appleton-laboratory

5 ECSAT, OXFORDSHIRE
Based on the same campus as the RAL, the European Centre for Space Applications and Telecommunications is the only ESA facility in the UK.
www.esa.int/About_Us/Welcome_to_ESA/ECSAT

6 REACTION ENGINES LTD
Founded in 1989 and also based in Oxfordshire, Reaction Engines is working on a new generation of rocket engine called SABRE, which operates up to five times the speed of sound.
www.reactionengines.co.uk

7 SURREY SATELLITE TECHNOLOGY LTD
Started by the University of Surrey, SSTL has been designing, building and operating small satellites for 30 years, and is a key part of the Disaster Monitoring Constellation project.
www.sstl.co.uk

8 MULLARD SPACE SCIENCE LABORATORY
UCL's Department of Space and Climate Physics researches theoretical physics and engineers space hardware, including cameras for 2018's ESA ExoMars lander.
www.ucl.ac.uk/mssl

9 HIGH DOWN, ISLE OF WIGHT
The former testing site for all 22 Black Knight and all four Black Arrow rockets before dispatch to Woomera. It is now owned by the National Trust and has an interesting exhibition on its history.
www.nationaltrust.org.uk/needles-old-battery-and-new-battery

10 GOONHILLY SATELLITE EARTH STATION, CORNWALL
At one time the largest satellite Earth station in the world, the site's first dish, Arthur, dates back to 1962 and provided the link with Telstar, to provide the first live transatlantic television feed. It is now a commercial communications and satellite operations centre.
www.goonhilly.org

BBC RADIO 4

Listen to a 2013 Woman's Hour interview with Helen Sharman
http://www.bbc.co.uk/programmes/b01slm1n

BBC one BBC TWO

You can watch Tim Peake's launch live on two *Stargazing LIVE* specials on BBC One and BBC Two on 15 December, and find out about his astronaut training in a BBC Two *Horizon* special in mid-December.

Galloway Forest Park

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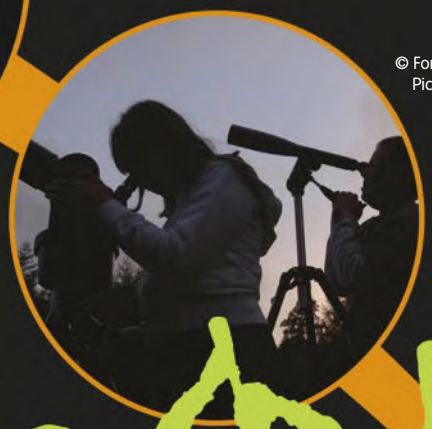
With astronomer friendly accommodation, **regular stargazing events**, welcoming astronomy groups and the Scottish Dark Sky Observatory; you can enjoy **spectacular views of the Milky Way,** meteor showers and planetary bodies over the next few months.

With big skies, **beautiful settings,** quiet roads, miles and miles of walking and biking trails and fantastic access to wildlife; the **Galloway Forest Dark Sky Park** delights both night and day.

New for 2015 – Galloway Forest Dark Sky Park Rangers. Hire a freelance Dark Sky Ranger and maximise your enjoyment of Galloway's star studded night sky.

For more information and contact details visit the dark sky park pages on our website **forestry.gov.uk/darkskygalloway**



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EXOPLANET HUNTERS

THE NEXT GENERATION

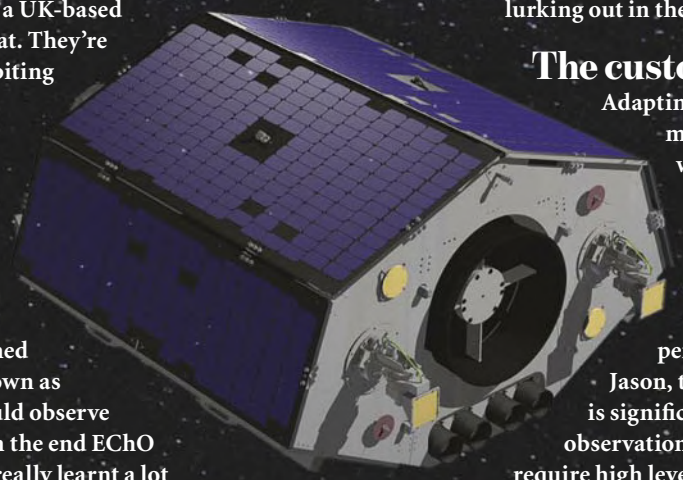
Will Gater tells the story of Twinkle, a British proposal to explore the alien worlds we have already detected but still know little about

Follow any space mission closely enough and at the pinnacle of its exploration – be it a flyby or hair-raising landing – you'll never fail to see a look of exhilaration and joy on the faces of the scientists working on the project.

Part of this, of course, is to do with the relief of seeing the mission's success. But for many such a moment will no doubt also represent the culmination of decades of work, perhaps even entire careers' worth of effort. This journey from an idea to the reality of an instrument, telescope or probe being in space can be a long one; and today the fate of any one concept is largely down to the major space agencies who decide who gets funding for what. Now, though, a UK-based team is attempting to change that. They're proposing to launch a small, orbiting observatory dubbed 'Twinkle' to study exoplanets, employing a very different set of methods to get into space.

The origins of Twinkle can be traced back to a proposal put forward by some of the team now working on the new mission concept. They had pitched an idea to ESA for a mission known as EChO, which, like Twinkle, would observe extrasolar planets. "Although in the end EChO was not selected for launch, we really learnt a lot through this experience," says University College London's Giovanna Tinetti, the science lead on the project. "We started to think how we could do this faster and for a better price."

▲ Right now illustrators have little to go on when creating art for far-flung worlds – Twinkle could help to change that



▲ Twinkle's design is based on the SSTL-300 platform, which is already used to examine Earth

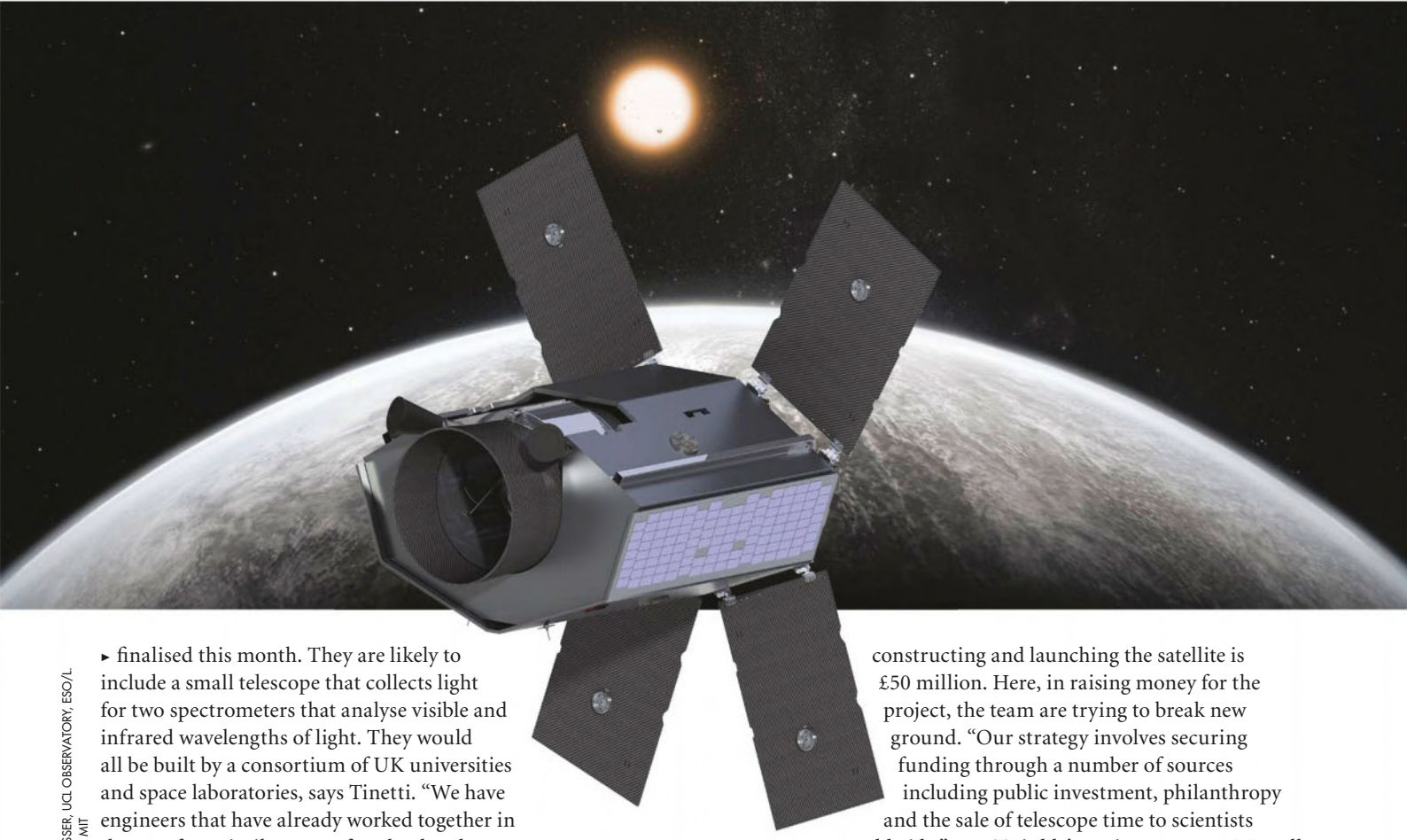
Missions like EChO typically take a decade or so to develop and launch, she says. The Twinkle team hopes to launch in late 2018. In order to achieve that goal, the astronomers realised they'd need to make use of existing technology rather than trying to develop their own satellite from scratch. "We really want to use off-the-shelf components as much as possible," says Tinetti.

The group eventually teamed up with Surrey Satellite Technology Ltd (SSTL), a Guildford-based firm that has manufactured many successful small satellites in recent decades. Between them they decided to base Twinkle on the company's SSTL-300 platform – a platform commonly used to examine our own planet, rather than ones lurking out in the Milky Way.

The customisation challenge

Adapting the platform design – which measures 1.5m long and about 1m wide – for an astronomy mission has naturally come with a few challenges. "Twinkle requires high precision in pointing coupled with a high level of stability over long observation periods," explains SSTL's Susan Jason, the project's lead engineer. "This is significantly different to the Earth observation missions: whilst these often require high levels of precision and stability, observations are over much shorter durations."

The details and specifications of the instruments and optics carried by Twinkle, which will actually make the exoplanet observations, should be ▸



TWINKLE/SSTL, ESO/M. KORNMESSER, UCL OBSERVATORY, ESO/L. CALÇADA, SSTL, ESA/C.CARREAU, MIT

▲ **Rather than discover its own exoplanets, Twinkle will take a closer look at the alien worlds already detected by other missions**

▸ finalised this month. They are likely to include a small telescope that collects light for two spectrometers that analyse visible and infrared wavelengths of light. They would all be built by a consortium of UK universities and space laboratories, says Tinetti. "We have engineers that have already worked together in the past for a similar type of payload and so we have a track record of being able to work together very efficiently and effectively."

Although the Twinkle team hopes to use proven space technology and their expertise in producing other science instruments, one substantial obstacle stands in their way: funding. The price tag for constructing and launching the satellite is £50 million. Here, in raising money for the project, the team are trying to break new ground. "Our strategy involves securing funding through a number of sources including public investment, philanthropy and the sale of telescope time to scientists worldwide," says Twinkle's project manager Marcell Tessenyi. Selling time slots to use the observatory would certainly have precedents in the world of ground-based astronomy. "There are some telescopes on the ground in various countries that are offering time on a telescope for a fixed price with various pricing models," says Tessenyi.

EYEING ALIEN WORLDS WITH AMATEUR OPTICS

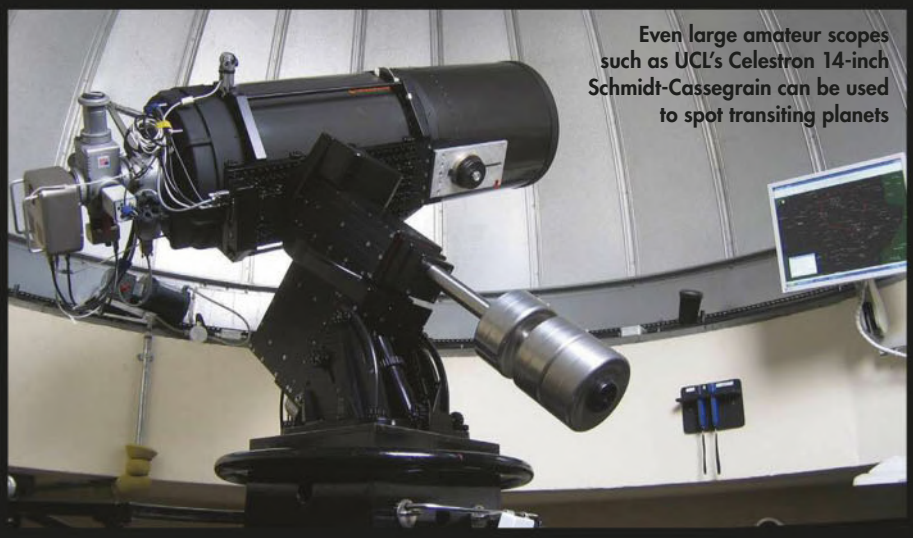
It's not just pros characterising exoplanets: amateurs are too

If Twinkle is successful it could provide a bounty of data for exoplanet researchers. But, as ever, when it comes to pushing boundaries amateurs are never far behind the pros. In recent years, some enterprising individuals and university groups have, using comparatively modest equipment, made ground-based detections of exoplanets transiting their stars.

Although not quite amateurs, University College London's Steve Fossey and students using the University of London Observatory have detected far off worlds with optics that many readers will recognise. Their kit includes 14-inch Schmidt-Cassegrains made by Celestron and a 10-inch Schmidt-Cassegrain manufactured by Meade.

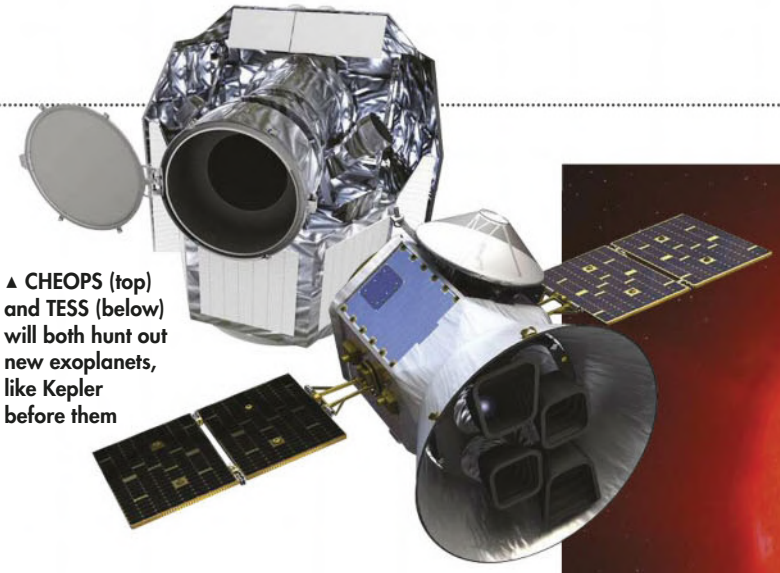
"Wide-field surveys have discovered many transiting planets around relatively bright stars – well within reach of exposures shorter than about a minute with small telescope apertures and off-the-shelf commercial CCDs that are commonly used by amateurs," says Fossey.

By recording the apparent change in brightness of a star during an exoplanet transit, and carefully analysing the CCD data, the group has been able to carry out impressive scientific work. "In 2009, we were one of the first teams to detect and publish the transit of the unusual, eccentric-orbit planet HD 80606b," says Fossey. "Our data enabled us to measure the planet's radius and orbit quite accurately, and were used in important follow-up studies of this system."

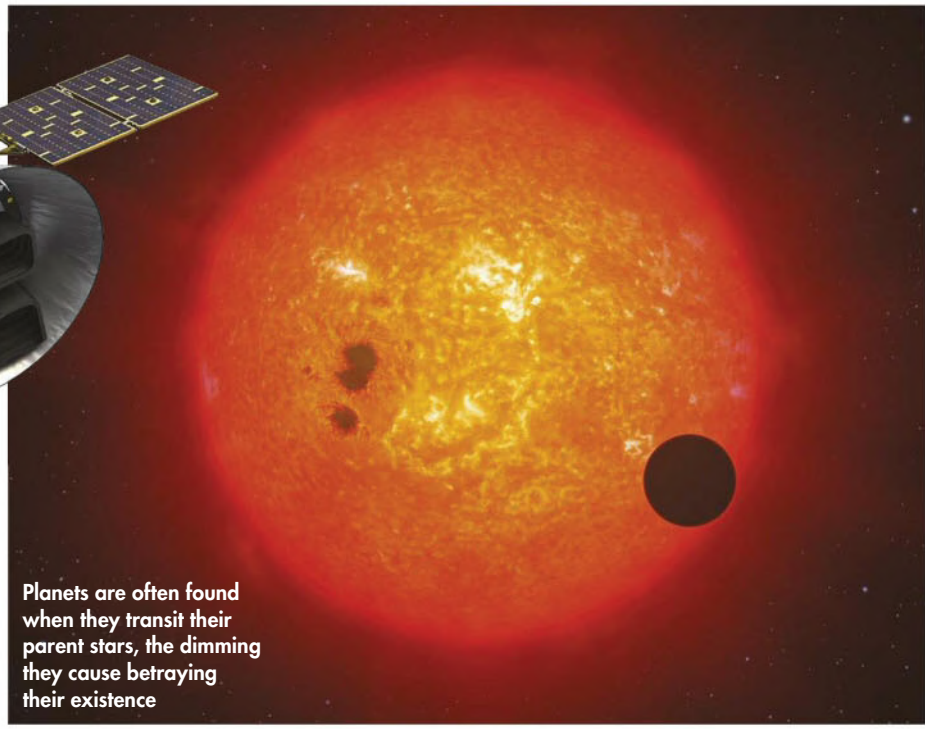


Even large amateur scopes such as UCL's Celestron 14-inch Schmidt-Cassegrain can be used to spot transiting planets

If you're reading this thinking that your own astronomical society's large scope might be able to detect alien worlds, take heart from recent developments at the Charterhouse Centre Observatory in Somerset. There, a team led by amateur Mark Woodland is in the process of preparing a 40-year-old Newtonian telescope with an 18.25-inch aperture for exoplanet transit observations. "For exoplanet detection, the generally stated precision is measuring to a 100th of a magnitude," says Woodland. "In our initial tests, with brighter objects, we have obtained a precision of 1,000th of a magnitude."



▲ CHEOPS (top) and TESS (below) will both hunt out new exoplanets, like Kepler before them



Planets are often found when they transit their parent stars, the dimming they cause betraying their existence

"So this is an exploratory idea to see if we can get some funding this way too."

The team also hopes to arrange a means for members of the public to make small donations, which will mainly be used to pay for outreach and education work, says Tessenyi. "In the longer term, we may also consider a crowdfunding campaign, but we want to ensure that this is linked to very specific objectives for the mission, like a time-critical piece of hardware, so that those supporting us are very clear about where their money is going."

If the mission team can raise the funds to get Twinkle off the ground, it won't fly on its own dedicated launcher. "We plan to be a secondary payload on a rocket commissioned for another satellite, effectively 'piggybacking' their launch," says Tessenyi. Once it's in orbit, Twinkle would be controlled via the mission operations centre at SSTL in Guildford, says Susan Jason. "This includes returning the science data from each of the observations back to the ground and distributing it directly to the users or to the planned science operations centre."

Different from Kepler

Unlike other exoplanet missions, like NASA's pioneering Kepler satellite, Twinkle wouldn't discover new extrasolar worlds. Instead it would probe planets that have already been found by other projects more deeply. The mission should have a plentiful supply of targets to choose from, says Tinetti. "Today we could already look at the atmospheres of at least 100 exoplanets," she says. And in the coming years several more orbiting observers will come online too, providing ever more worlds for Twinkle to study. These include ESA's CHEOPS (Characterising Exoplanet Satellite) mission, which should launch in late 2017 and NASA's TESS (Transiting Exoplanet Survey Satellite) which will fly into space on a SpaceX Falcon 9 rocket in 2017. "We'll be flooded by planets in the next 10 years," suggests Tinetti.

Twinkle would work by watching the crucial moment when one of its target planets passes in front of its parent star. When it makes this 'transit', starlight floods through the atmosphere of the planet and out the other side in our direction. As the light passes through the exoplanet's atmosphere

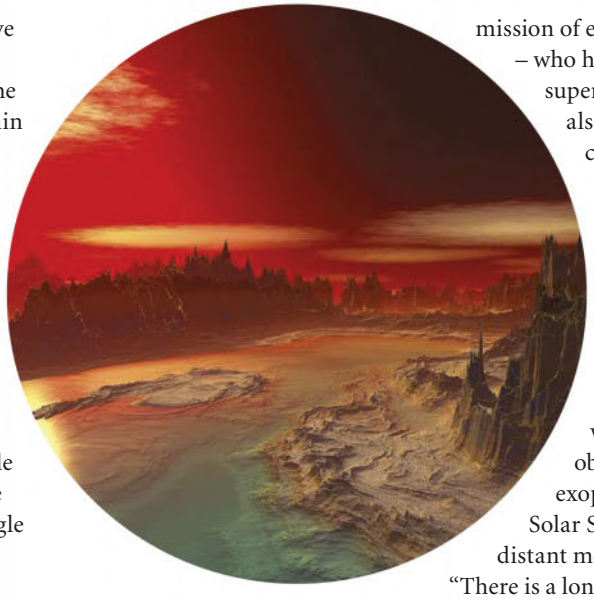
▲ Should all go to plan, Twinkle will be managed from the mission operations centre at SSTL in Guildford

gases in it absorb certain wavelengths, leaving chemical markers that manifest themselves as distinctive, dark lines in the spectrum of the star's light. Twinkle's spectrographs would be able to reveal these lines and, once they're decoded, the team would be able to work out the make-up of the exoplanet's atmosphere.

The astronomers would also use Twinkle to gather observations when the planets are eclipsed, as they pass behind their stars, which can also help to reveal clues about their atmospheres. "One moment before the eclipse you have the light coming from the planet and the star together and then when the planet is behind the star you're left with the star alone, so you can use this information to subtract the contribution of the star," explains Tinetti.

Twinkle's infrared observing capability will be crucial for probing these exoplanet atmospheres, as these wavelengths are where the 'fingerprints' of many interesting molecules lie. "Molecules like water vapour, carbon dioxide, ammonia and ▸

▸ carbon monoxide all have a distinctive signature in the infrared," says Tinetti. Infrared observations can also reveal the temperatures at different altitudes within an exoplanet's atmosphere and even if there are variations in temperature across its globe. Tinetti hopes that for some of the planets they'll be able to make repeat observations. "That's exactly what you want to do if you want to study weather on a planet, you don't want just to have a snapshot in time," she says. Through observing many planets – of varying ages – Twinkle may even be able to provide an insight into the way these worlds evolve. "It's like looking at a single planet through time," explains Tinetti.



▲ **Molecules such as water vapour and methane have distinctive signatures that Twinkle should be able to detect**

Pioneer potential

So what do other exoplanet researchers make of the proposed mission? "In the US, the next big mission for exoplanets is TESS," says David Kipping, a professor of astronomy at Columbia University. "The whole point of TESS is to find planets which are amenable for detailed follow-up and so Twinkle perfectly complements this function." Since the mission aims to study a large number of distant targets, it could also provide something of a first for the field, he says. "We will not get enough telescope time on the general purpose James Webb Space Telescope [slated for launch in 2018] to observe this many planets, so Twinkle could be our first survey mission of exoplanet atmospheres." Kipping – who has experience in crowdfunding a supercomputer for his own research – also believes this sort of funding system can help get members of the public engaged with the work astronomers are doing. "I think people who donate will feel a sense of pride when they read about Twinkle's future discoveries, knowing that they helped make this science happen," he says.

According to Tinetti the mission would have a small amount of observing time – when not looking at exoplanets – that could be used to study Solar System objects such as asteroids, distant moons and even Uranus and Neptune. "There is a long list of things that you can do," she says. So as Twinkle seeks to reveal the secrets of faraway worlds, we may also find that it illuminates the mysteries of those much closer to home.

ABOUT THE WRITER

Will Gater (@willgater) is an astronomer and journalist. He is the author of several books and presents live astronomy shows for Slooh.

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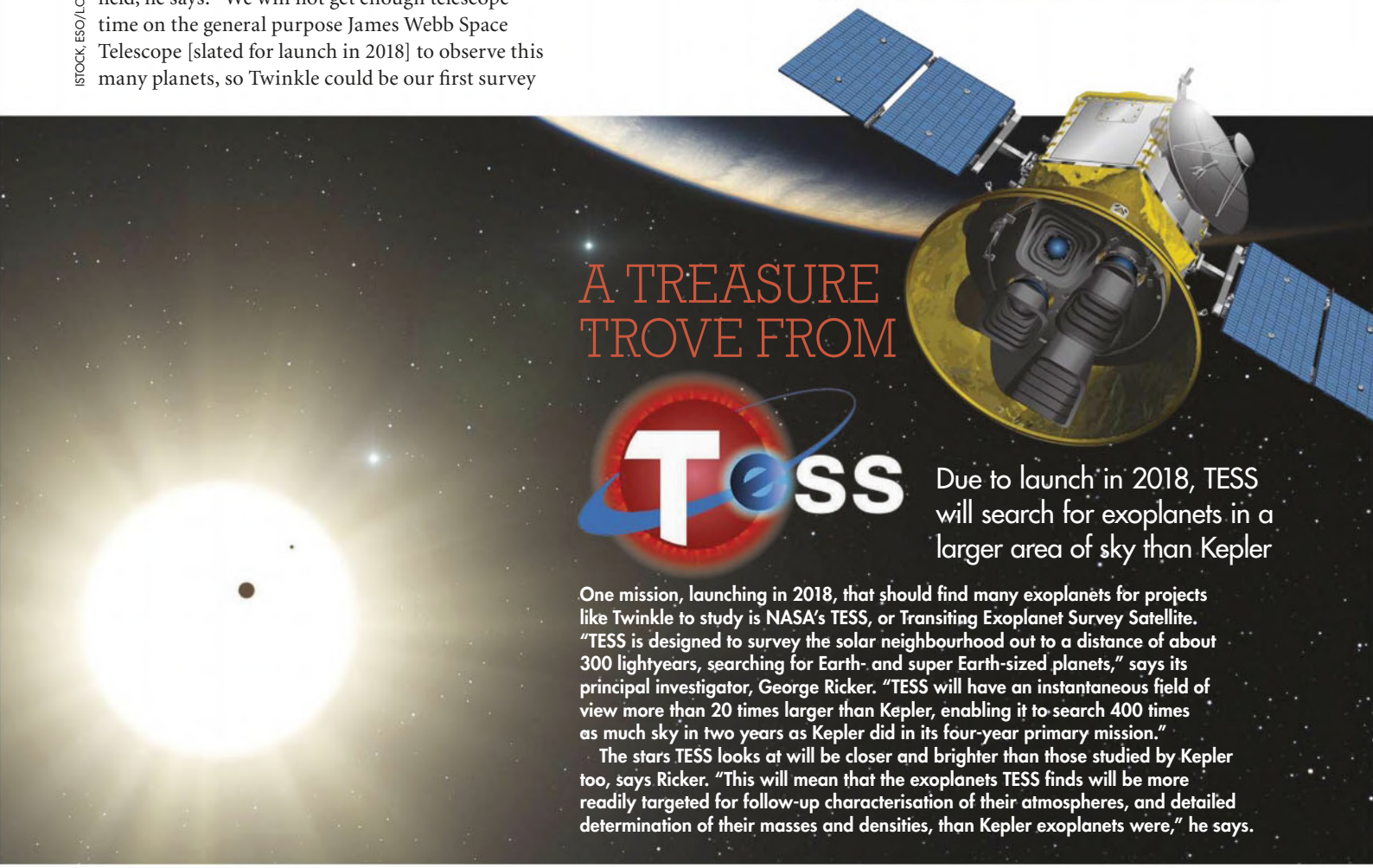

A TREASURE TROVE FROM TESS

Due to launch in 2018, TESS will search for exoplanets in a larger area of sky than Kepler

One mission, launching in 2018, that should find many exoplanets for projects like Twinkle to study is NASA's TESS, or Transiting Exoplanet Survey Satellite. "TESS is designed to survey the solar neighbourhood out to a distance of about 300 lightyears, searching for Earth- and super Earth-sized planets," says its principal investigator, George Ricker. "TESS will have an instantaneous field of view more than 20 times larger than Kepler, enabling it to search 400 times as much sky in two years as Kepler did in its four-year primary mission."

The stars TESS looks at will be closer and brighter than those studied by Kepler too, says Ricker. "This will mean that the exoplanets TESS finds will be more readily targeted for follow-up characterisation of their atmospheres, and detailed determination of their masses and densities, than Kepler exoplanets were," he says.

ROYAL OBSERVATORY GREENWICH

IC443 © Patrick Gilliland

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

Astronomy Centre,
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18 September 2015 – 26 June 2016

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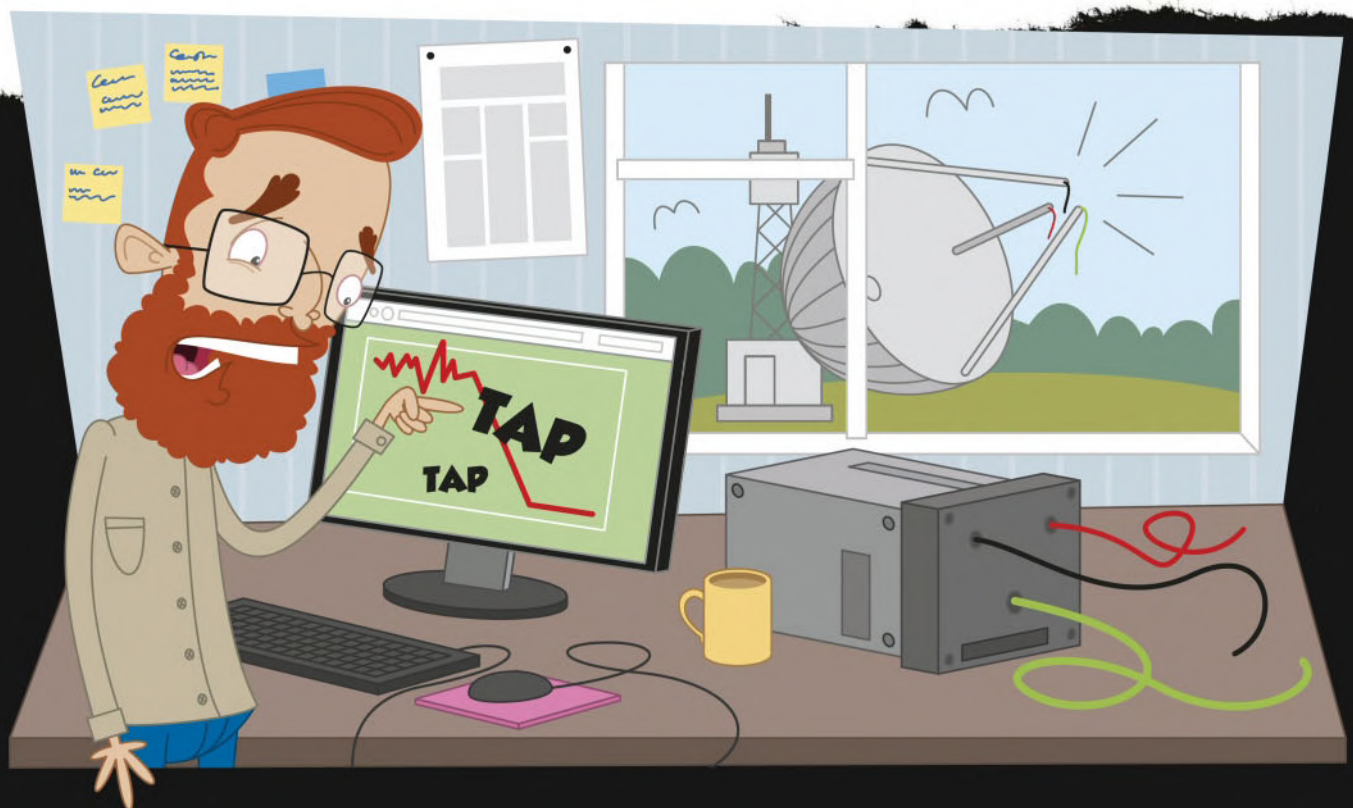
ROYAL MUSEUMS GREENWICH

Kooges, Blunders and Bullets

The working life of a pro astronomer is measured, objective and rational. But that doesn't mean everything is destined to go smoothly, as **Anders Thygesen** discovers

Professional astronomers are highly trained individuals, but even so, weird things sometimes happen in this business, many of which are unlikely to happen anywhere else. It is, after all, a somewhat special environment. What follows are some of the oddest incidents that have been captured in the scientific record.



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The clues didn't add up

At the CSIRO Parkes Observatory, a radio telescope in Australia, a poor undergraduate student had a hard time getting any observations. After many frustrating hours trying to make the telescope behave, the student's supervisor arrived to collect his own data. With him, he carried a radio receiver he found on the ground outside. Shrugging, the supervisor put the receiver on a table and began his own observations, but alas, no data came through.

At sunrise, the daytime staff casually pointed out a receiver-shaped hole in the antenna, providing a fairly obvious explanation for the lack of data. Apparently the receiver had become loose and fallen off the telescope. You might have thought that a receiver lying on the ground would have been a hint to the problem, but no one had made the connection between this and the issues with getting observations.

MIND YOUR LANGUAGE, YOUNG MAN

Most astronomical observations require darkness. Not just 'turn off the light' darkness, but preferably 'have I gone blind?' darkness. This is why observatories are typically in remote locations where light pollution is minimal. Once, a young George Coyne was observing at the Vatican Observatory in Castel Gandolfo, Italy, when someone opened the door to the dome, flooding it with light and ruining the observations. "Close that bloody door!" shouted Coyne, after which the visitor promptly vanished, closing the door behind him. The following day, Pope Paul VI reminded him: "My son, you should be in better control of your temper." The Pope must have forgiven the outburst, since Coyne became the observatory director in 1978.

BLAME THE ANIMALS, IT WASN'T OUR FAULT!

Occasionally, lack of data is due to errors made by astronomers, but sometimes there are other culprits. After a thorough investigation, astronomers examining 'hot spots' in M82 in 1987 reported that a lack of data from one of their antennas was due to no fault of their own, but because a snake was draped across it. They concluded that "even though this snake, or rather a 3ft section of its remains, was caught in the act of causing an arc between the transmission lines, we do not consider it responsible for the loss of data. Rather we blame the incompetence of a red tailed hawk who had apparently built a defective nest that fell off the top of the nearby transmission tower."

THE SCOPE THAT SHOOK OFF BULLETS

In February 1970, a disgruntled employee arrived at the McDonald Observatory in Texas carrying a handgun. After firing a shot at his supervisor, which fortunately missed, he fired seven point-blank shots at the telescope mirror. Since the mirror is 31cm thick it did not shatter as intended, so he proceeded to attack it with a hammer. Shortly after the sheriff arrived and arrested the employee, later reporting that the telescope had been destroyed due to the large hole in the mirror. This was quickly corrected when the observatory director explained that the central hole was intentional. He elaborated that the bullet holes had only diminished the mirror's light collecting efficiency by one per cent. The bullet holes are still visible in the mirror today.

THE TELESCOPE THAT RAN OVER A TRUCK

The 2.5m Nordic Optical Telescope in La Palma has a peculiar design: it is not just its dome that rotates but the whole building, including the entry staircase. In September 2005, staff needed to hoist equipment from the observatory's truck into the dome, so they backed the truck up close to the telescope. Afterwards, the staff went about their business and rotated the telescope to its parking position. However, no one had remembered to move the truck. The entry staircase rammed into it and the telescope effectively ran over the car. Cars all too frequently run things over, but rarely do they get run over themselves – let alone by an entire building. The truck got a big dent, but survived the encounter.

THE WORLD'S LARGEST BUG ZAPPERS

The monumental 305m Arecibo radio telescope and the 70m antenna at the Goldstone Deep Space Communications Complex are among the largest telescopes in the world. When not used as movie sets, they are used to observe asteroids and planets, which they do by pumping hundreds of kilowatts of ultra-high frequency signals into space. While this does not pose any danger when the signal is distributed across the thousands of square metres of the main dishes, the same cannot be said about the area immediately surrounding the transmitter. Here, the signal is significantly more concentrated. At Arecibo, birds can get caught inside the dome containing the transmitter, and it is easily possible for birds and insects to fly into the beam path of the 70m antenna at Goldstone. If this happens while the beams are on, birds and insects are very rapidly microwaved, briefly turning the telescopes into very big and expensive bug zappers. The charred leftovers then need to be removed with high-tech equipment, such as sticks with wads of sticky tape. The dishes of both telescopes would doubtless make for excellent BBQ spots, just as long as the chefs watched where they put their hands.

BODGE JOBS

Astronomers constantly try to improve their instruments so more accurate and exciting discoveries can be made. Sometimes this requires years of dedicated work, but in other cases a simple fix using your kid's toys can do the trick. At the Nordic Optical Telescope in La Palma, work was ongoing to improve the stability of the spectrograph, where the light enters through an optical fibre, and one way of achieving this was to physically shake the fibre. Rather than buying an expensive, custom-made mechanism, the instrument scientist took matters into his own hands and built a prototype from his son's Lego bricks. The prototype worked and the performance of the spectrograph was improved, but the Lego was not quite sturdy enough for continual use (and his son wanted his toys back), so it was dismantled. Encouraged by this initial success, the staff went searching for another vibrating contraption, and came up with a more robust replacement – an old foot massager, which is still in use today. A similar mechanism was tested at the Wendelstein Observatory in Germany, where an old car wiper motor took the place of the massager.

ABOUT THE WRITER

Anders Thygesen has a PhD in astronomy and is the author of the AstroAnecdotes blog. Read it at www.astroanecdotes.com.

ILLUSTRATIONS BY TOM HUGHES/WWW.HUGHES-ILLUSTRATION.COM

The Sky Guide December

This month sees the return of the annual Geminid meteor shower, arguably the best of the year. If the clouds stay away, this year's display has the promise of being quite spectacular because the Moon will be almost new.

Written by Pete Lawrence

Pete Lawrence is an expert astronomer and astrophotographer with a particular interest in digital imaging. As well as writing *The Sky Guide*, he appears on *The Sky at Night* each month on BBC Four.

PETE LAWRENCE

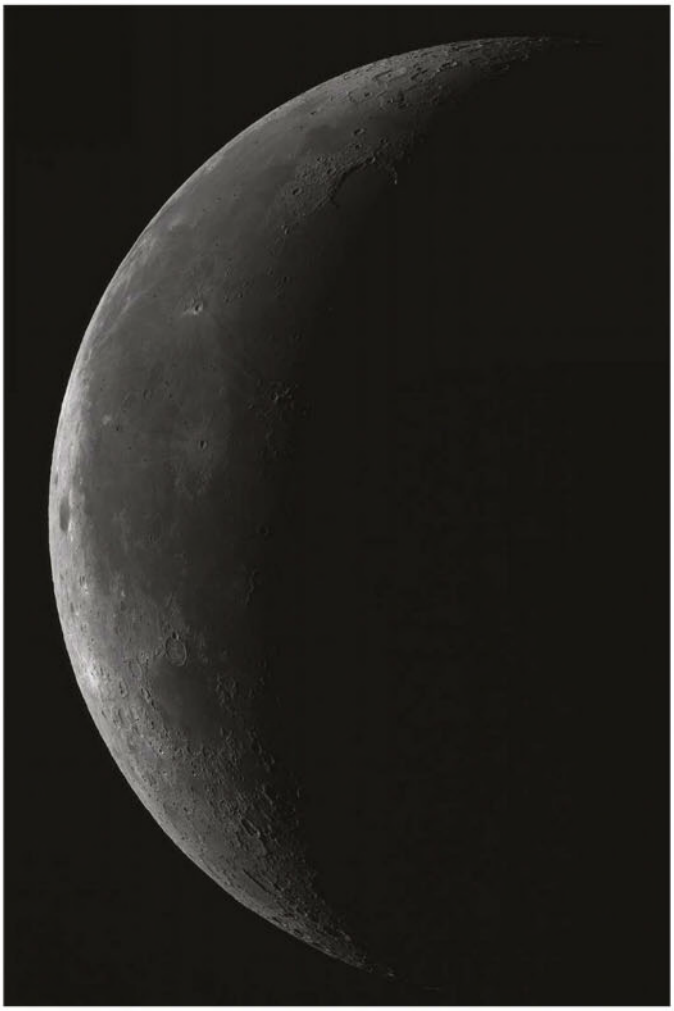
Highlights

Your guide to the night sky this month

This icon indicates a good photo opportunity

1 TUESDAY ▶
Saturn moves from Scorpius into Ophiuchus, where it will remain through the whole of 2016. Although not visible at the start of December, the Ringed Planet will have moved far enough from the Sun to be visible in the early morning sky by the end of the month.

2 WEDNESDAY
Comet C/2013 US10 Catalina is potentially a naked-eye object, visible low in the east-southeast from around 05:30 UT. At present the comet is passing north, up the sky, just to the east of mag. +4.2 Kappa ( ) Virginis.

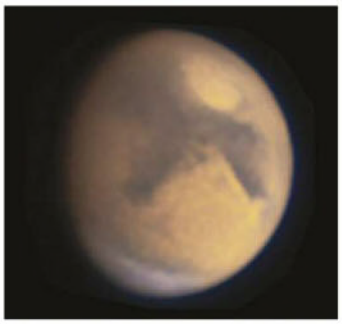


6 ◀ SUNDAY
A 23% lit waning crescent Moon sits 2° east of Mars in this morning's sky – the pair rise in the east around 03:00 UT.

With the Moon now in the early morning sky, the next two weeks are an ideal time to take our deep-sky and binocular tours.

7 MONDAY
The Moon's planetary tour continues, with its 16%-lit waning crescent now 4.75° to the west of brilliant Venus as they rise in the east-southeast around 04:30 UT. They will remain close throughout the day, just over 2° apart as they approach the west-southwest horizon at 13:30 UT.

12 SATURDAY ▶
If you have a very flat southwest horizon, it may be possible to spot mag. –0.6 Mercury 6.5° below the 1%-lit waxing crescent Moon this evening. Give it 10-15 minutes after the Sun has well and truly set, then sweep the area with binoculars.



14 ◀ MONDAY
Mars is just 15 arcminutes south of mag. +4.4 Theta ( ) Virginis. This separation is about equal to the apparent radius of the full Moon. Catch the planet and star 20° up in the southeast at 05:00 UT.

20 SUNDAY
The 64%-lit waxing gibbous Moon will be 2° southwest of the planet Uranus. The best time to catch them will be around 00:30 UT, very low in the west. Using binoculars, look for the mag. +4.3 Epsilon ( ) Piscium. Uranus is the brightest object midway between this star and the Moon.

21 MONDAY
Although it seems like the wrong time of year to speak of the summer star Antares (Alpha (α) Scorpii) it may be possible to spot it just above the horizon in the southeast about 45 minutes before sunrise. Why would you want to? Because Saturn is also there, 6° above Antares.

22 TUESDAY
The northern hemisphere's winter solstice occurs today at 04:48 UT.

The Ursid meteor shower peaks tonight, but the waxing gibbous Moon will interfere. The Moon will be above the horizon as the sky darkens, and remain visible until around 05:30 UT on the 23rd.

24 THURSDAY
Mars is just 3.5° north of white mag. +1.0 Spica (Alpha (α) Virginis). They can be seen in the early hours from 03:00 UT onwards, and present a great chance to image the extreme colour contrast between them. They are also currently similar in brightness.

PETE LAWRENCE X 7

4 FRIDAY
The 41%-lit waning crescent Moon lies 2.25° south of Jupiter at 03:00 UT. Catch them rising in the east from around 00:30 UT. Jupiter is currently shining at mag. –1.8, which will make it a good match for the Moon.

5 SATURDAY
Venus marks the way! The magnificently bright planet will be 5° west of potentially naked-eye comet C/2013 US10 Catalina. They will appear separated by less than 5° until the 10th, although their relative orientations will change. See page 51.

8 TUESDAY
This morning the 9%-lit crescent Moon will be on the eastern side of Venus and so you'll have to catch it a bit later than yesterday. Look out for our neighbour 6° from the mag. –4.0 planet around 05:00 UT.

9 WEDNESDAY
Comet C/2013 US10 Catalina will be very close to mag. +4.1 Iota (ι) Virginis, this morning and tomorrow morning. As a potentially naked-eye comet, this should make it fairly easy to spot, low in the east-southeast. Try to locate the comet around 05:30 UT, before the start of dawn.

13 SUNDAY ▶
The fabulous Geminid meteor shower reaches its peak tonight. This is arguably the best meteor shower of the year and with the Moon new on 11 December, conditions couldn't be better. See page 50.

15 ◀ TUESDAY
The Orion Nebula, probably the most viewed and photographed deep-sky object visible from the northern hemisphere, is at its highest point due south around midnight. As a bonus, the Moon's currently out of the way, leaving the sky lovely and dark.

31 THURSDAY ▶
The 68%-lit waning gibbous Moon is 5.5° west of Jupiter at 07:00 UT. With the Moon as a guide, it should be possible to keep Jupiter in view even after the Sun has risen.

Comet C/2013 US10 Catalina is 3° south of mag. +0.2 Arcturus (Alpha (α) Boötis).

What the team will be observing in December

Pete Lawrence "The Geminid meteor shower is my favourite of the year but to see it at its best you need to have the Moon out of the way. Fortunately, this year, that's exactly what's going to happen!"

Paul Money "On the last few nights of the year I'll be trying to spot all the major planets in one night along with comet C/2013 US10 Catalina, the Moon, dwarf planet Ceres and minor planet Vesta."

Steve Marsh "I've been trying to get more afocal shots of the Moon recently and its close pairing with Mars on the 6th is too good an opportunity to miss."

Need to know

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object lies on the celestial 'globe'.

HOW TO TELL WHAT EQUIPMENT YOU'LL NEED

NAKED EYE
Allow 20 minutes for your eyes to become dark-adapted

BINOCULARS
10x50 recommended

PHOTO OPPORTUNITY
Use a CCD, planetary camera or standard DSLR

SMALL/MEDIUM SCOPE
Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE
Reflector/SCT over 6 inches, refractor over 4 inches

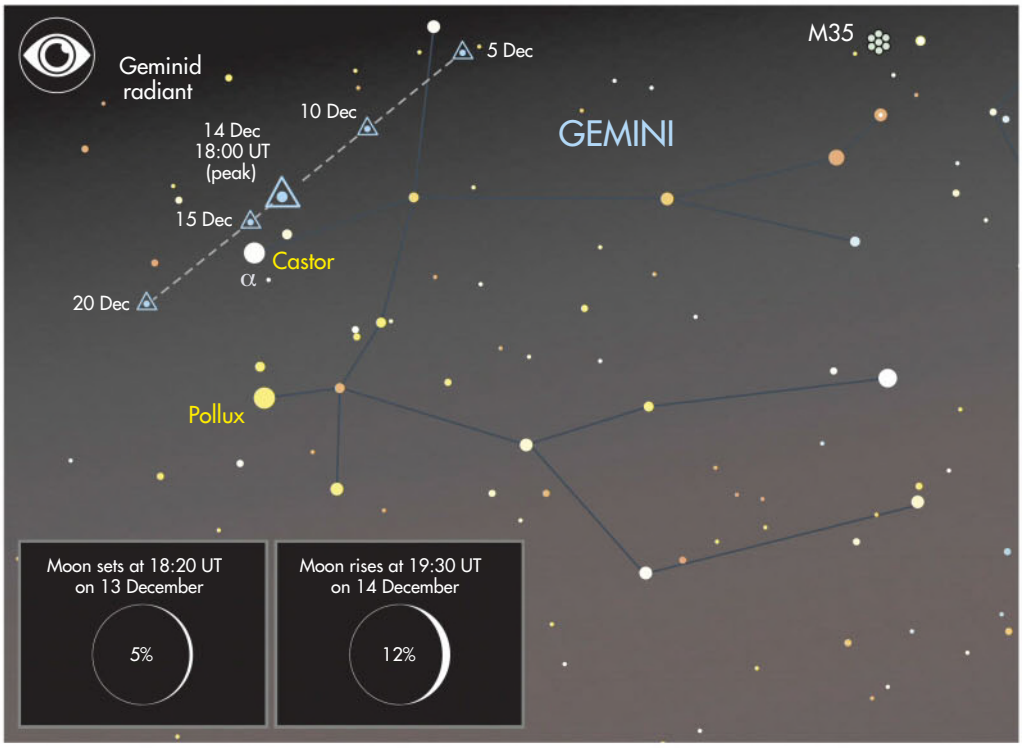
Getting started in astronomy

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing your first scope.

DON'T MISS... 3 top sights

The Geminid meteor shower

WHEN: Shower peak is on the night of 13/14 December



The Geminid radiant is close to the bright star Castor – all Geminid trails should point back to this location

THE GEMINID METEOR shower reaches its peak on the night of 13/14 December and the new Moon on the 11th is perfectly timed to give us dark skies. The Geminid shower is arguably the most active of the year, and unlike its more comfortable rival (August tends to be warmer than December) can be watched for the many hours of darkness that make up a long winter's night.

The shower's zenithal hourly rate reaches a peak value of 120 meteors per hour. This is predicted to occur at 18:00 UT on 14 December, but the peak tends to be broad. Near maximum, rates should continue for about a day centred on this time. Consequently, the best night for Geminid watching will be that of 13/14 December with the 14/15 December potentially putting on a decent show as well.

There are other factors that kick in to adjust the zenithal hourly rate. These include radiant altitude, and the time of night your meteor watch takes place. After midnight, the Earth will have turned to encounter the meteoroids that impact on Earth's atmosphere to produce the meteor trails head on. This raises the energy of impacts and the brightness of the trails that are seen.

The radiant is located close to mag. +1.9 Castor (Alpha (α) Geminorum) in Gemini around the time of peak activity, and this places it at its highest point in the sky, due south, around 02:00 UT. From the centre of the UK, the radiant reaches a very respectable height of 68°. The radiant's location near to Castor means that it's easy to trace a line back to check whether any meteor you've seen is a Geminid. During the peak, a trail must line up with the star in order to be part of the shower.

Geminid meteors impact our atmosphere at a speed of 35km/s – slower than the 59km/s Perseids. Slower meteors are more photogenic because their trails stay on each part of a camera sensor for that bit longer. This means that the Geminids should be an exciting shower to try and photograph too.

The best way to enjoy the Geminids is to place a sunlounger somewhere away from any light interference, lie back and keep looking up. Look to a height around 60° up and in any direction. Meteors will be shortest close to the radiant. For decent trail lengths, a location roughly 60° away from the radiant's azimuth works well. Do remember to wrap up warm though as December nights can be very cold. The Geminid meteor shower is active from 4-17 December.

NEED TO KNOW

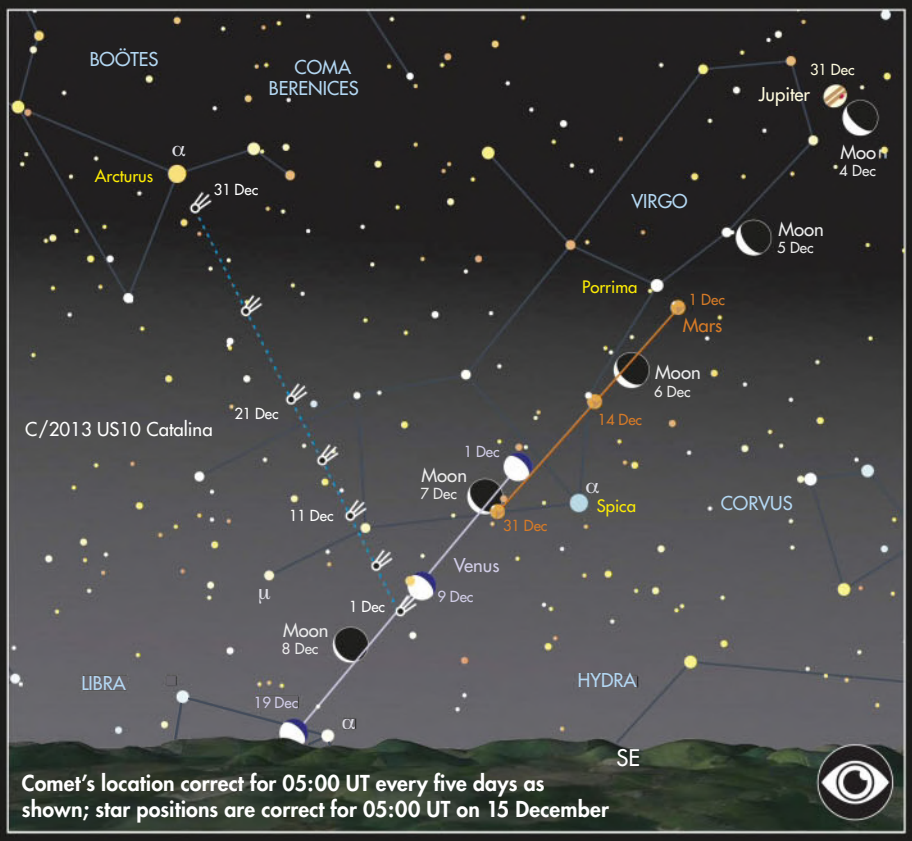
The zenithal hourly rate of a meteor shower is the expected number of meteors seen under perfect conditions with the radiant point of the shower overhead.

Meteor trails should be brighter after midnight, when Earth turns into the stream of debris that creates the shower

PETE LAWRENCE X4

A possible naked-eye comet

WHEN: All month, best mid-month when the Moon's out of the way



Comet's location correct for 05:00 UT every five days as shown; star positions are correct for 05:00 UT on 15 December

DURING DECEMBER, COMET C/2013 US10 Catalina finally starts to become easier to see for those of us located in the UK. And the good news is that C/2013 US10 Catalina should be a naked-eye comet. It's expected to be around the mag. +5.0 mark, as it climbs higher in our morning sky at the start of December. It'll be close to the 4th-magnitude star Kappa ( ) Virginis, but will slowly crawl northward, through Virgo and into Boötes. At the end of the month, the comet will be very close to bright orange Arcturus (Alpha (α) Boötis), and this will provide an easy way to locate it.

The Moon will be in its waning phases at the start of December, approaching the region containing the comet as a 15%-lit crescent on the morning of the 7th. Even though this will be a very thin phase for the Moon, its light can still interfere with the view of a delicate extended target such as the head and tail of a comet.

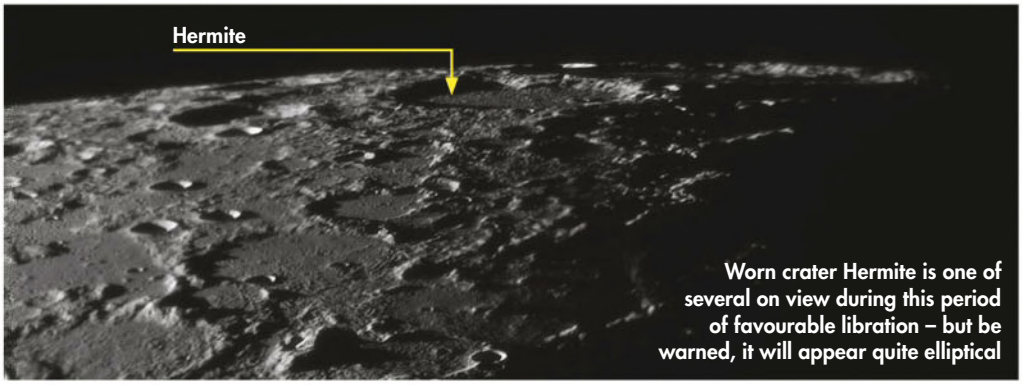
Talking of bright things, the brilliant dot of Venus will be close by at the start of December too. Both comet and planet appear to sidestep one another during the early part of the month. Closest approach will be around 7 December, when they will be a little under 4° apart.

The Moon is new on 11 December as the comet continues to climb higher in the morning sky. A higher altitude will make C/2013 US10 Catalina easier to see, aided by it reaching its brightest magnitude around this period, possibly up to mag. +4.0.

The best tool to spot the comet will be a pair of binoculars. However, once you've located it, don't forget to look at the same region with just your eyes to see if you can see that rare astronomical sight – a naked-eye comet.

A good libration for the Moon's northern limb

WHEN: 20-26 December



Worn crater Hermite is one of several on view during this period of favourable libration – but be warned, it will appear quite elliptical

THE MOON APPEARS to rock and roll on its axis as it trundles around the sky each month. This effect, called libration, allows us to see an extra nine per cent of the lunar surface as it progresses through its orbit, compared to what we'd normally see if the Moon were truly locked to show us just one face.

The rocking and rolling occurs in such a way that it brings features at certain positions around the Moon's limb into good view from time to time. These 'libration zone' features are interesting to hunt down, but can be a challenge to identify because they tend to appear foreshortened. What may be a well-defined area of large craters can soon become a jumble of thin ellipses when seen edge on.

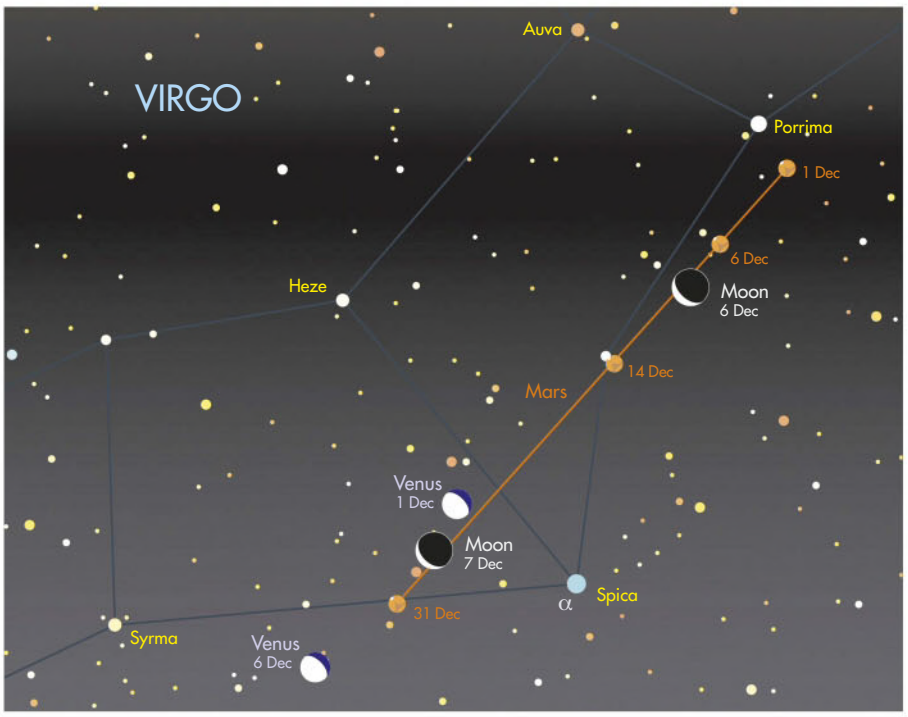
The appearance of libration zone features are further complicated by the Moon's phase, which has to be favourable in order to see anything meaningful. Libration and phase work together to bring the Moon's northern region into a favourable view from 20-26 December. So if you're lucky enough to get something 'astronomical' for Christmas, this is a great time to try out your new kit. Turn to page 60 for details on how to create a lunar mosaic of the Moon's northern limb.

The planets

PICK OF THE MONTH

MARS

BEST TIME TO SEE: 31 December 06:00 UT
ALTITUDE: 25°
LOCATION: Virgo
DIRECTION: South-southeast
FEATURES: North polar cap, light and dark surface features
EQUIPMENT: 8-inch or larger telescope

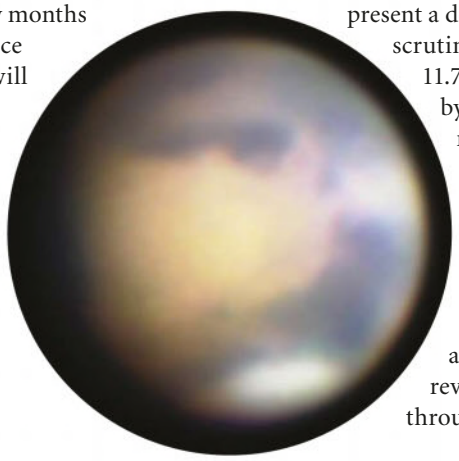


The Red Planet starts the month near Porrima in Virgo, crossing the constellation through December

MARS IS SLOWLY coming back into view. Despite being visible all month long in the morning sky, the planet remains quite distant from Earth and consequently, its apparent diameter is still quite small.

Mars is at opposition on 22 May 2016 and over the next few months the planet's appearance through a telescope will change significantly. At the start of December, the planet has an apparent size of 4.8 arcseconds. By the month end, this rises to 5.5 arcseconds, a 14% increase.

At the end of January 2016 it'll measure 6.8 arcseconds, growing to 8.6 arcseconds by the end of February. Through March, Mars will present a decent sized disc for scrutiny through a scope, 11.7 arcseconds across by the end of the month. This trend continues with Mars reaching 18.6 arcseconds at the end of May, when it's closest to us.



PETE LAWRENCE X 3

Mars is small at present, but you may still be able to glimpse a white polar cap

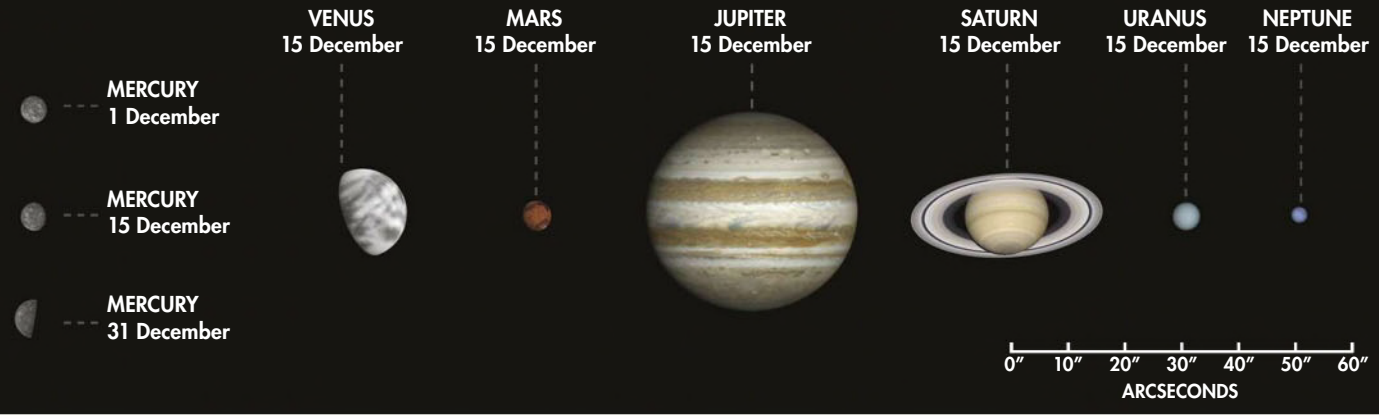
Rapid growth in apparent diameter reveals more detail through a telescope. The one downside to the 2016 opposition is that the maximum altitude of Mars will remain low from the UK.

At present it's around mag. +1.5 but this too will increase to an impressive mag. –2.1 at opposition. Currently, a view through an eyepiece will show the planet to be at a 92% gibbous phase. With care, you might catch a glimpse of its bright north polar cap. If the conditions are good and you pile on the power, you may even be able to see a hint of the dark markings that pattern its surface.

Remember though, whatever you manage to see during December, over the next few months, the view can only get better. Consequently, this is a great time to start observing the planet, as the changes in appearance can then be really appreciated.

THE PLANETS IN DECEMBER

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



VENUS

BEST TIME TO SEE:
1 December 06:30 UT
ALTITUDE: 20°
LOCATION: Virgo
DIRECTION: Southeast

At the start of December Venus shines at an intense mag. –4.2. Catching a glimpse of it when your eyes are still dark adapted is quite a shock. It rises four hours before the Sun at the start of the month, but this decreases to 3 hours and 15 minutes by the 31st. A 16%-lit waning crescent Moon is 4.75° west of Venus on the morning of the 7th. If you miss this, the following morning sees a 9% waning crescent Moon 6° east of the planet. A telescope will show Venus to have a 67%-lit, 17-arcsecond disc on 1 December. By the 31st, the disc will have shrunk to 14 arcseconds and appear 77% lit.

JUPITER

BEST TIME TO SEE:
31 December 05:00 UT
ALTITUDE: 41°
LOCATION: Leo
DIRECTION: South

Jupiter is a morning object that improves all month. It is mag. –2.1 and presents a 39 arcsecond disc at the end of December. A 41%-lit waning crescent Moon is close on the 4th, Jupiter positioned 2° from the Moon's northern limb at 03:00 UT. A repeat meeting occurs on the 31st, with the Moon around 6° west of the planet at 05:00 UT. Jupiter manages to culminate (reach its highest point) in darkness from the middle of the month.

URANUS

BEST TIME TO SEE:
1 December 20:30 UT
ALTITUDE: 43°
LOCATION: Pisces
DIRECTION: South

Uranus culminates in darkness all month. The planet is mag. +5.8, which is theoretically visible to the naked eye given a good dark sky. On the 20th, a 64%-lit waxing gibbous Moon lies 2° southwest of Uranus at 00:30 UT – see them low in the west.

NEPTUNE

BEST TIME TO SEE:
1 December 18:00 UT
ALTITUDE: 27°
LOCATION: Aquarius
DIRECTION: South

Neptune remains visible during December, but is to the west of south as darkness falls at the end of the month. At mag. +7.9, you'll need binoculars at least to see the planet. It is in Aquarius, roughly a quarter of the way along a line from mag. +4.8 Sigma ( ) Aquarii to mag. +3.7 Lambda ( ) Aquarii.

MERCURY

BEST TIME TO SEE:
31 December 16:30 UT
ALTITUDE: 6° (low)
LOCATION: Sagittarius
DIRECTION: Southwest

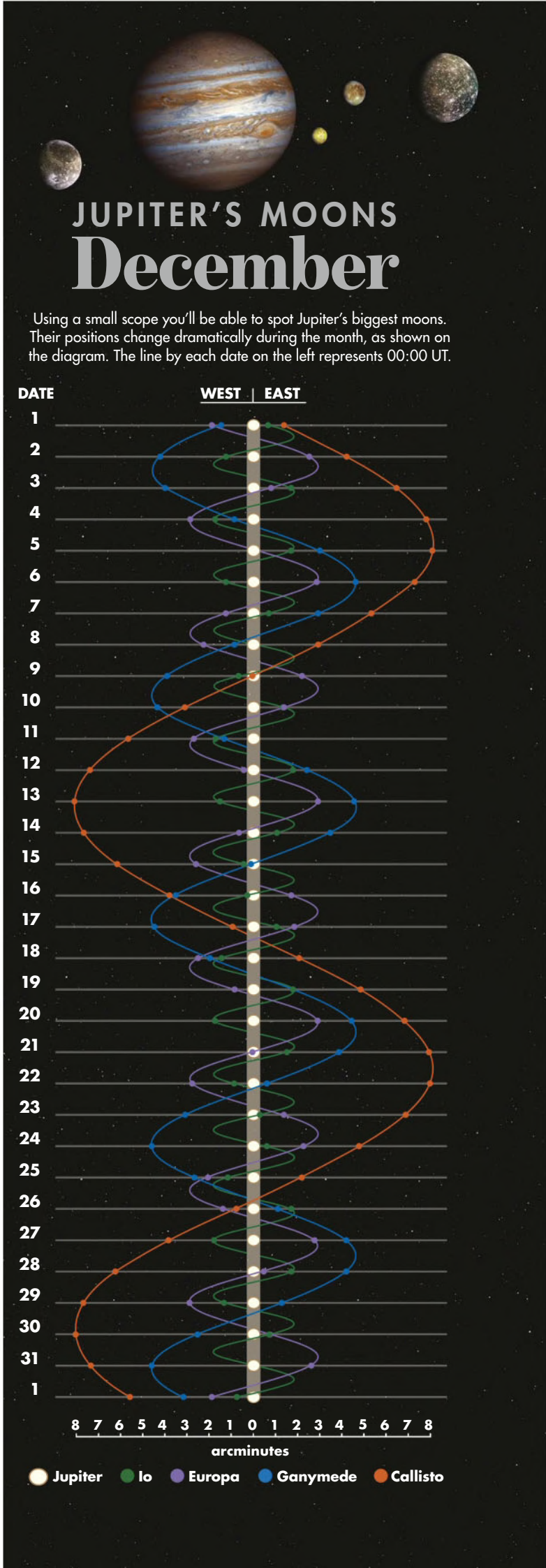
Mercury is poorly positioned at the start of December, almost setting with the Sun. Things do improve and, by the 18th, mag. –0.6 Mercury sets an hour after the Sun and may be seen before this, low above the southwest horizon. Greatest eastern elongation occurs on the 28th, when the mag. –0.5 planet is separated from the Sun by 19.7°. If you can get a look at it through a telescope at this time, it'll appear with a 61%-lit phase 6 arcseconds across.

SATURN

BEST TIME TO SEE:
31 December 07:15 UT
ALTITUDE: 7° (low)
LOCATION: Ophiuchus
DIRECTION: Southeast

Saturn moves into the constellation of Ophiuchus at the start of December. The planet is not well positioned for serious observing, but may be seen visually from mid-month onwards, low in the southeast before sunrise.

See what the planets look like through your telescope with the **field of view calculator** on our website at:
http://www.skyatnightmagazine.com/astronomy-tools



The Northern Hemisphere

KEY TO STAR CHARTS

- *Arcturus* — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Cygnet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- N / E / S / W — COMPASS AND FIELD OF VIEW
- MILKY WAY

WHEN TO USE THIS CHART

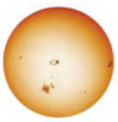
1 DECEMBER AT 00:00 UT
15 DECEMBER AT 23:00 UT
31 DECEMBER AT 22:00 UT

On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

THE SUN IN DECEMBER*



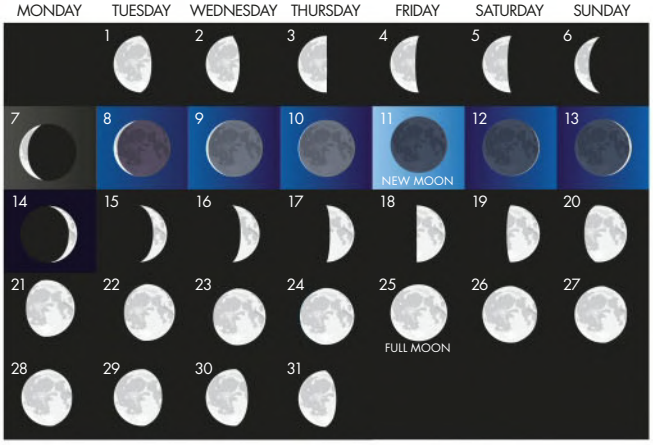
DATE	SUNRISE	SUNSET
1 Dec 2015	08:02 UT	15:55 UT
11 Dec 2015	08:15 UT	15:50 UT
21 Dec 2015	08:23 UT	15:52 UT
31 Dec 2015	08:26 UT	15:59 UT

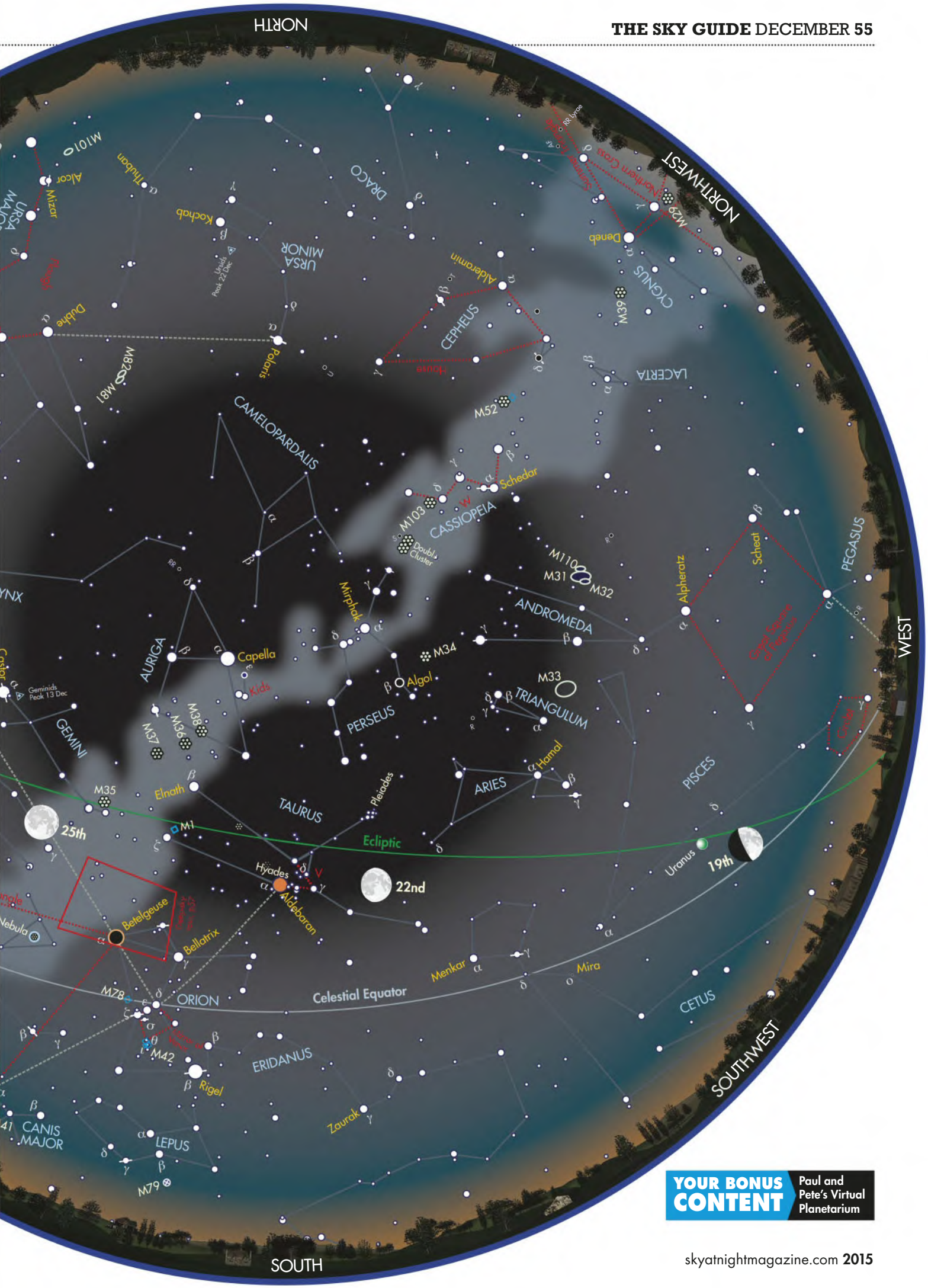
THE MOON IN DECEMBER*

MOONRISE TIMES

1 Dec 2015, 22:10 UT	17 Dec 2015, 11:48 UT
5 Dec 2015, 01:23 UT	21 Dec 2015, 13:38 UT
9 Dec 2015, 05:39 UT	25 Dec 2015, 16:36 UT
13 Dec 2015, 09:28 UT	29 Dec 2015, 20:57 UT

*Times correct for the centre of the UK



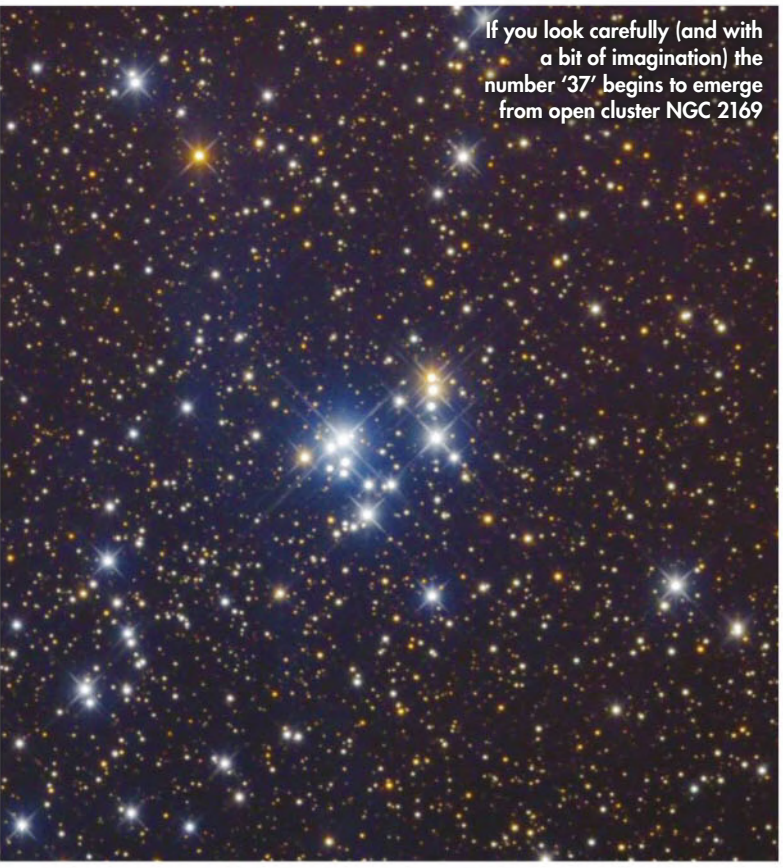


YOUR BONUS CONTENT Paul and Pete's Virtual Planetarium

Deep-sky tour

There's more to the winter constellation of Orion than its famous namesake nebula

☑ Tick the box when you've seen each one



If you look carefully (and with a bit of imagination) the number '37' begins to emerge from open cluster NGC 2169

1 COLLINDER 69

Mention Orion and you immediately think of the Orion Nebula, M42, located in the Hunter's sword. However, as the constellation lies close to the Milky Way, it's full of rich objects other than the famous nebula. Our first target is an easy one, best suited to your lowest power eyepiece. Collinder 69 is a sparse open cluster centered around the double star Meissa (Lambda ( ) Orionis), which marks Orion's head. Collinder 69 contains around 20 stars over an area 70 arcminutes across. Meissa is the dominant member of this five-million-year-old cluster. The primary star is mag. +3.5; you'll need a high power to spot its mag. +5.6 companion, which lies 4.4 arcseconds away. ☐ **SEEN IT**

2 NGC 2022

Collinder 69 was a gentle introduction to this month's tour; the ones that follow, starting with NGC 2022, may require a bit more effort. NGC 2022 is a 12th-magnitude planetary nebula located one-third of the way along the line which connects Meissa to mag. +0.5 Betelgeuse (Alpha (α) Orionis). It's pretty easy to overlook with a small telescope at low power, as the nebula looks quite star-like. However, increased magnification with a 6-inch scope will start to show its 20-arcsecond disc quite clearly. A larger instrument may show that the nebula is not perfectly round and has a hint of darkness at its centre. A 16-inch or larger scope should be able to show the nebula's 15th-magnitude central star. ☐ **SEEN IT**

3 HARO 3-75

Haro 3-75 is another planetary nebula, located north of Meissa. To find it, star hop from Meissa to the 6th-magnitude star HIP 26386, 1° to the north-northeast. Keep going for the same distance again to mag. +7.8 HIP 26625. Extend the line between these two stars about one-third of the distance again and you'll reach Haro 3-75. This is a 13th-magnitude planetary, 25 arcseconds across. It's just visible with a 10-inch scope given dark skies, and for the best views you'll need a high magnification. Haro 3-75 has the appearance of being quite circular and also concentric thanks to its extended bright circular core. ☐ **SEEN IT**

4 ABELL 12

Our third and final planetary is something of a challenge. At mag. +12.4 it should be relatively straightforward in a 10-inch scope, and it's also easy to find being right next to the mag. +4.1 star Mu (μ) Orionis. However, it's Mu that complicates things because the delicate 40 arcsecond disc of the nebula is positioned so that it appears to almost touch the star. Having such a bright object nearby is troublesome and makes Abell 12 a much harder challenge than it would otherwise be. Our recommendation is to use an OIII filter if you have one. If you get a view of it, the nebula's disc appears bordered by an incomplete ring. ☐ **SEEN IT**

5 NGC 2141

The pressure's off with our two final objects, which are both relatively straightforward open clusters. The first is NGC 2141, which is located 48 arcminutes to the north-northeast of Mu Orionis, the mag. +4.1 star that makes Abell 12 so hard to see. There's no such problem identifying mag. +9.4 NGC 2141 though, as the cluster is rich in faint stars and relatively compact with its members being confined to an area 10 arcminutes across. The main part of the cluster, off to the west, has a roughly heart-shaped appearance, with a darker broad 'lane' running approximately north-south along the eastern edge of the heart. ☐ **SEEN IT**

6 NGC 2169

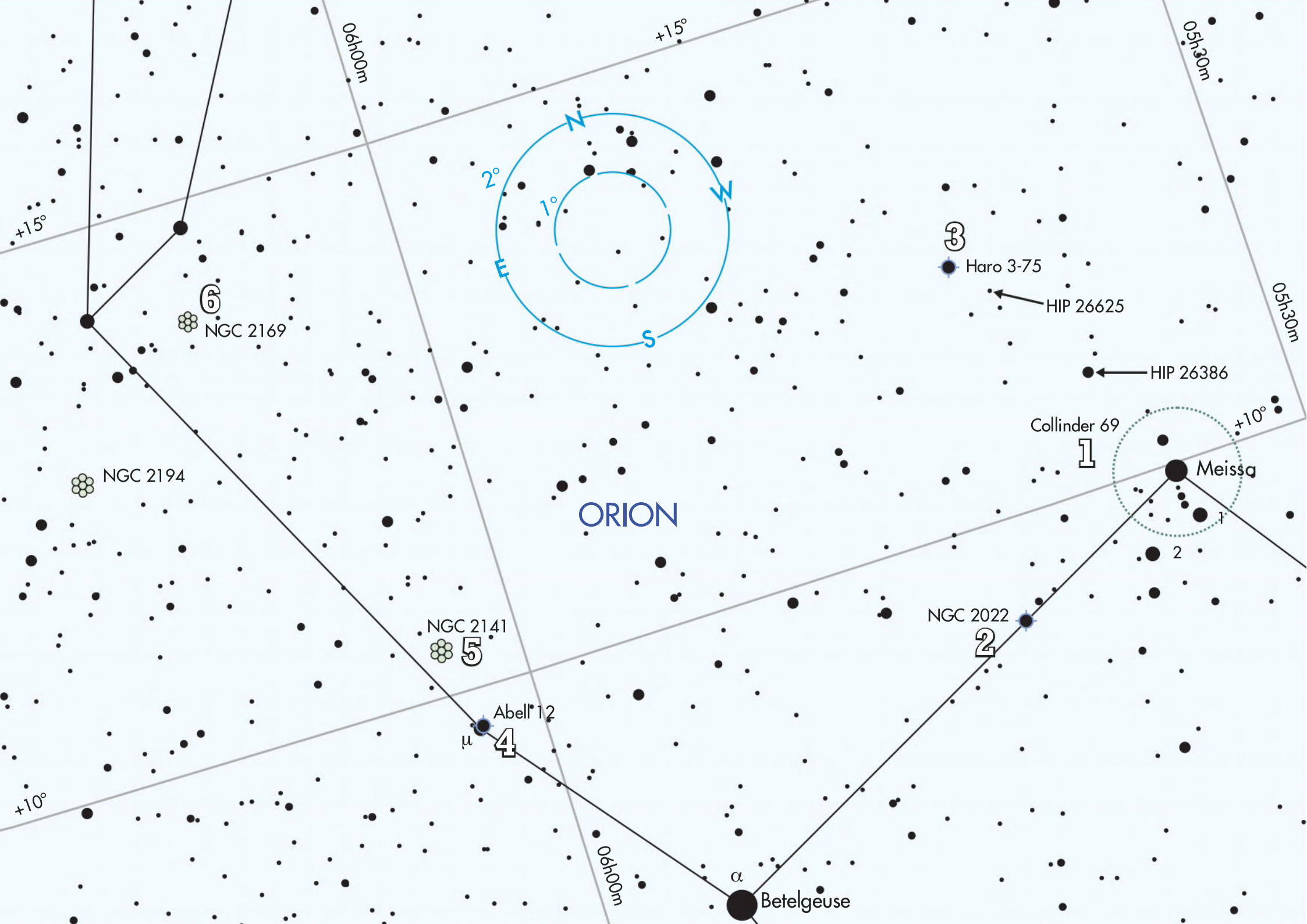
Our final target, NGC 2169, is located 3.75° to the north and slightly east of NGC 2141. It is fairly bright at mag. +5.9 and about 7 arcminutes across. It contains around 30 stars, the brightest of which is close to mag. +7.0. The remarkable thing about this cluster is the fact that its stars appear to spell out the number '37'. Unsurprisingly, this is often referred to as the '37 Cluster'. This is of course a complete fluke with no cosmic significance. ☐ **SEEN IT**

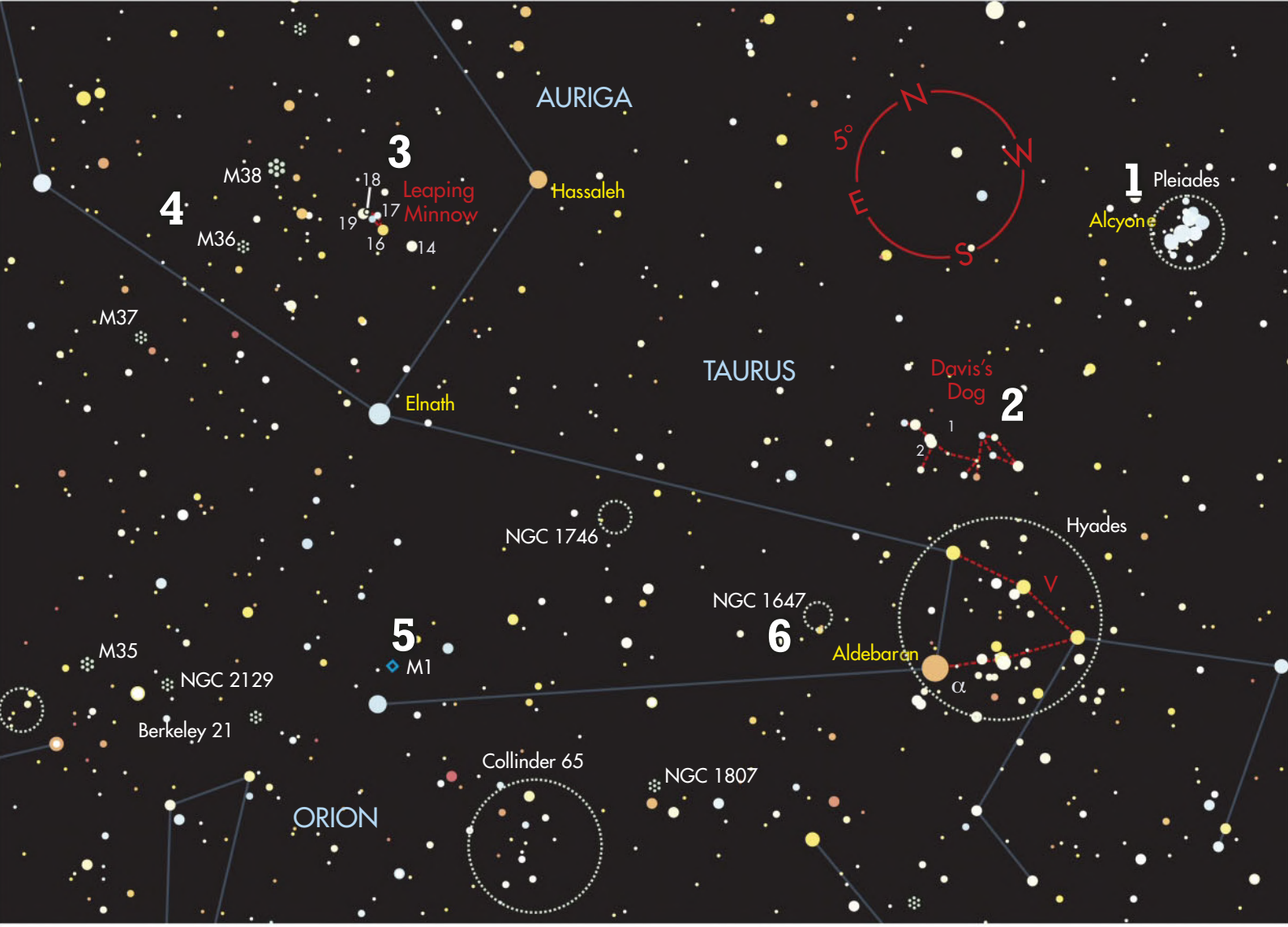
THIS DEEP-SKY TOUR HAS BEEN AUTOMATED

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

YOUR BONUS CONTENT Print out this chart and take an automated Go-To tour

CHART: PETE LAWRENCE, PHOTO: GÜNTER KERSCHHUBER/CCDGUIDE.COM


06h00m
+15°
05h30m
N
W
E
S
2°
1°
3
Haro 3-75
HIP 26625
HIP 26386
6
NGC 2169
NGC 2194
ORION
Collinder 69
1
Meissa
+10°
1
2
NGC 2022
2
NGC 2141
5
Abell 12
μ
4
α
Betelgeuse



Binocular tour

December delivers an abundance of asterisms and the first of Messier's vexations

With Stephen Tonkin

☑ Tick the box when you've seen each one

1 THE PLEIADES

10x 50 We start this month's tour with what is a classic binocular object, the Pleiades, designated M45 and commonly known as the Seven Sisters. Although this open cluster is an easy naked-eye object, it takes small- or medium-sized binoculars to reveal its full glory. In the words of Tennyson, these young, hot, blue-white stars "glitter like a swarm of fireflies tangled in a silver braid." Incidentally, this does not refer to the asterism Ally's Braid, a string of 7th- to 9th-magnitude stars that span just under half a degree, hanging down from Alcyone (Ally), the brightest of the Pleiades. ☐ **SEEN IT**

2 DAVIS'S DOG

10x 50 From the Pleiades, navigate 7.5° in the direction of the Hyades where, in a region spanning about 3.5° by 1.5°, you will find an group of 15 or so stars of mag. +8.0 and brighter. Three brighter stars form its head, and a string of four that includes wide double star Kappa^{1} (^{1}) and Kappa^{2} (^{2}) Tauri the tail. Its short legs are made of fainter stars. I see it as a dachshund viewed obliquely, but apparently John Davis, for whom this asterism is named, saw a beagle. What do you see? ☐ **SEEN IT**

3 LEAPING MINNOW

10x 50 To find our third asterism of this month's tour, navigate a bit more than 4° east of mag. +2.7 Hassaleh (Iota ( ) Aurigae). Here you will find a little group of approximately mag. +5.0 stars, just over 1° across, that includes 16, 17, 18 and 19 Aurigae. In a pair of 10x50s you should see that this group of stars forms the shape of a fish. If you look to the northeast of the Minnow you will see the 'Splash', which includes mag. +5.0 Phi ( ) Aurigae. Counting the Splash, you should see at least 30 stars. ☐ **SEEN IT**

4 A TRIO OF CLUSTERS

10x 50 Putting Phi Aurigae on the right of the view, you should see two fuzzy patches, one above the centre and the other below. The upper, slightly larger one is the Starfish Cluster, M38. The other is M36, a cluster similar to the Pleiades but 10 times farther away. Now put M36 near the top of the field and another fuzzy patch, larger and brighter than either of the previous two, is visible near the bottom of the field of view. This is M37, which is 500 lightyears further than the other two. ☐ **SEEN IT**

5 THE CRAB NEBULA

15x 70 We continue the aquatic theme with an object that every amateur astronomer should know of. On 28 August 1758, Charles Messier was seeking the predicted return of Halley's Comet. He happened upon what he thought was a comet, a tiny (5 arcminute) misty patch 1.1° northwest of mag. +3.0 Zeta ( ) Tauri. The patch hadn't moved a week later, so he knew that it was not the comet, and M1 became the first in his list of objects for comet hunters to avoid. Today we know it is a mag. +8.4 supernova remnant; you'll need a dark, transparent sky to observe it. ☐ **SEEN IT**

6 NGC 1647

15x 70 Put mag. +0.9 Aldebaran (Alpha (α) Tauri) in the southwest of the view and opposite it you will find the open cluster NGC 1647, also designated Melotte 26. This sparse cluster is easy to identify at low power, and a pair of 15x70s should reveal 20-30 stars against a background glow just under 1° in diameter. Take a closer look at brightest of these stars: you should be able to see that it is actually a double star with a separation of 33 arcseconds and magnitudes of +8.9 and +9.3. ☐ **SEEN IT**

CHARTS AND PICTURES: PETE LAWRENCE

Moonwatch

W Bond

THE WALLED PLAIN W Bond is conspicuous for a number of reasons. First, its name is a little odd as lunar features don't tend to include the initial of the person they are named after. In this case it's named after William Cranch Bond, an American astronomer who, together with his son G P Bond, is credited as having taken some of the earliest photographs of the Moon. In the past it has gone under the name Bond and W C Bond.

As walled plains go, W Bond is also conspicuous because of its shape. Rather than the more typically round profile you'd expect, here we see a feature that's decidedly rectangular. It's an old feature and this has played a part in shaping it, its walls having been eroded and modified over time. However, through a telescope, its regular shape is quite striking.

The floor of W Bond looks relatively flat under high illumination but when the Sun gets low in the lunar sky, oblique lighting shows it to be quite bumpy and rough. There are a number of craters inside its rectangular rim, the most prominent of which is 15km W Bond B towards the eastern corner. Half the size again, 7km W Bond C lies 20km to the northeast.

These craters are a useful navigational tool to help you look for a curious rille that appears to run along part of the east-west diagonal of the rectangle. The rille is visible under good lighting conditions, but when the light comes from the wrong angle it disappears without trace. The best time to pick it up is during the waxing phase when the terminator is relatively close by – say around 60 per cent illumination. It's in the late waning phases that the rille vanishes from view. As it's a rather narrow feature, it best suits larger scopes or high-resolution imaging setups.

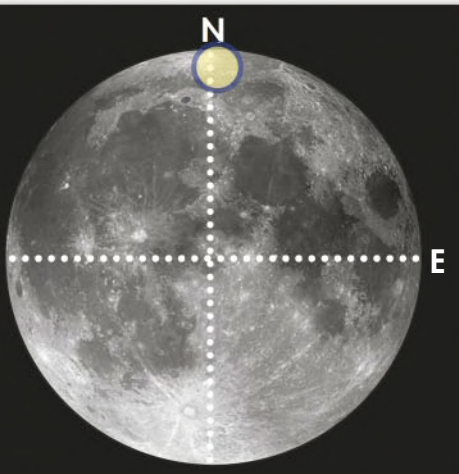
The rugged floor of W Bond contrasts well with the flat lava of Mare Frigoris, which runs to the southwest, clipping the southern corner of W Bond's perimeter. In fact the corner itself is marked by what looks like a lava-filled crater. This is Archytas B (36km wide). Compare its appearance with the similarly sized Timaeus (33km), which sits further northwest, in the middle of the southwest edge of W Bond. Whereas Archytas B appears completely flat, Timaeus is a more typical crater with a sharp rim and central mountain peak.

Epigenes (55km) sits just off the northwest of W Bond. It is a well-defined crater with a flat floor and offset central mountain. The wall dividing it from W Bond is pronounced, and on the other side sits 18km Epigenes A.

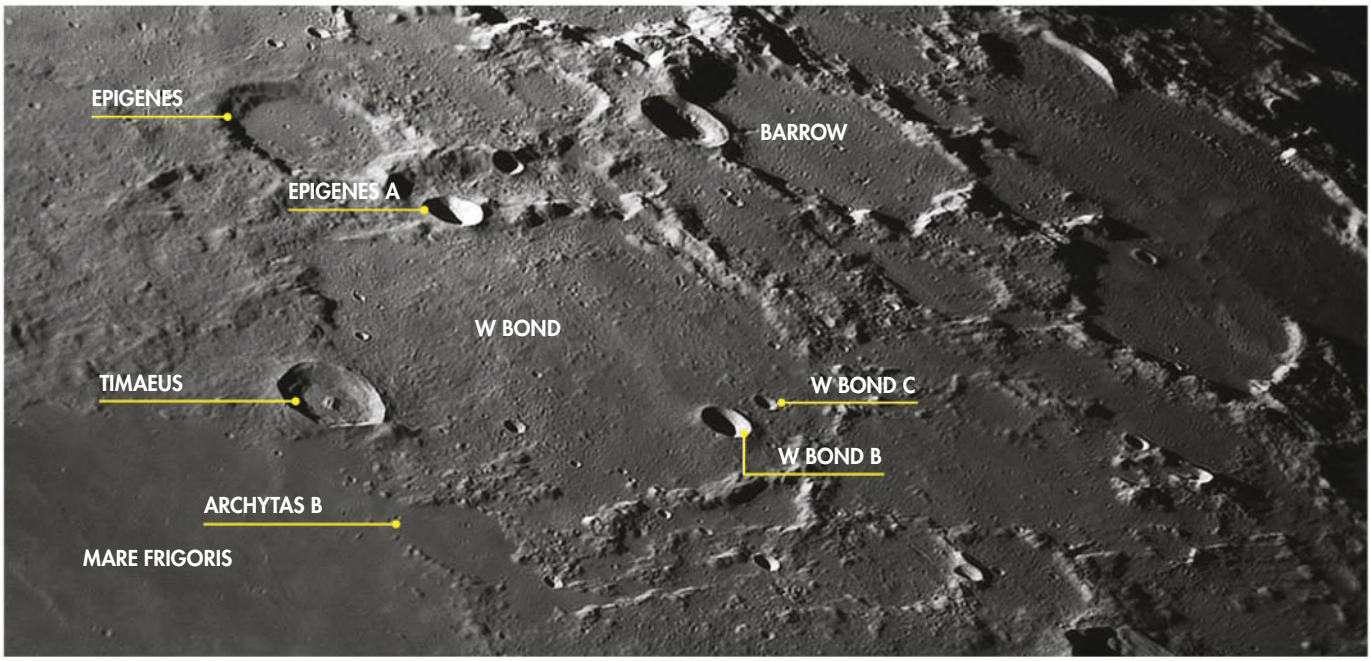
There is a peculiar regularity to the features in this part of the Moon. As an example, look at Barrow (93km) to the northeast of W Bond. It too has a certain rectilinear appearance, the southwest part of its rim almost parallel to the northeast edge of W Bond. This is a fantastic part of the Moon to study, especially when the Sun's light is low and oblique, causing dramatic shadows to dominate the view.

STATISTICS

TYPE: Walled Plain
SIZE: 160km²
AGE: 3.8-3.85 billion years
LOCATION: Latitude 65.4°N, longitude 3.5°E
BEST TIME TO OBSERVE: First quarter or 6 days after full Moon (1-3 December, 18-19 December and 31 December)
MINIMUM EQUIPMENT: 10x binoculars



"It's an old feature, its walls having been eroded and modified over time"



Astrophotography

Mosaicing the Moon's northern craters

RECOMMENDED EQUIPMENT

High frame rate camera (monochrome recommended), red- or infrared-pass filter, telescope, driven equatorial mount

KEY TECHNIQUE

BEAT THE GAP WITH OVERLAP

A well-constructed lunar mosaic will convey the sheer awesome majesty of the lunar surface. Creating a mosaic which doesn't show joins nor has any gaps can be tricky to achieve, especially if you've never done it before. The real trick is to make sure you have enough overlap. In theory, getting enough overlap should be relatively easy to do and indeed it is as long as you know the Moon well. If you don't you'll need a few tricks – which we show you in the step by step on the facing page.

IT'S AMAZING HOW we sometimes take the Moon for granted. When it's big, bright and familiar face shines down throughout a cold December night, it's easy to imagine the groans let out by distant deep-sky imagers desperate for true darkness. But the Moon has a charm of its own, and is well worth taking the effort to investigate – especially if you can't do anything else because of it. This month, we are going to look at mosaicing part of the surface.

The ever-changing phase of the Moon creates some amazing shadow effects, revealing detailed nuances in valleys, crater floors or in vast mountain ranges. Illuminated obliquely, even modest mountain peaks can cast daunting shadows across the vast lunar lava plains.

However, the changing shadows are only part of the story because the familiar near-side face of the Moon isn't quite as constant as you might imagine. The Moon speeds up when it reaches perigee, the closest point to us in its orbit. At its furthest orbital distance, apogee, it travels at its slowest. This variation allows us to see around the sides of the Moon from time to time. Then there's the fact that the Moon's orbit is inclined to the ecliptic plane by around 5º. This allows us to see a little over the top or under the bottom of the Moon. Taken together, these effects are known as libration, and they reveal about nine per cent more of the lunar surface than you'd see if the Moon's face were truly locked in one permanent orientation relative to Earth.

Getting optimal libration to see certain features is down to luck and good timing. If a portion of the Moon's globe is tilted towards us, the phase must also be favourable. If not, the feature will be in the lunar night and invisible.

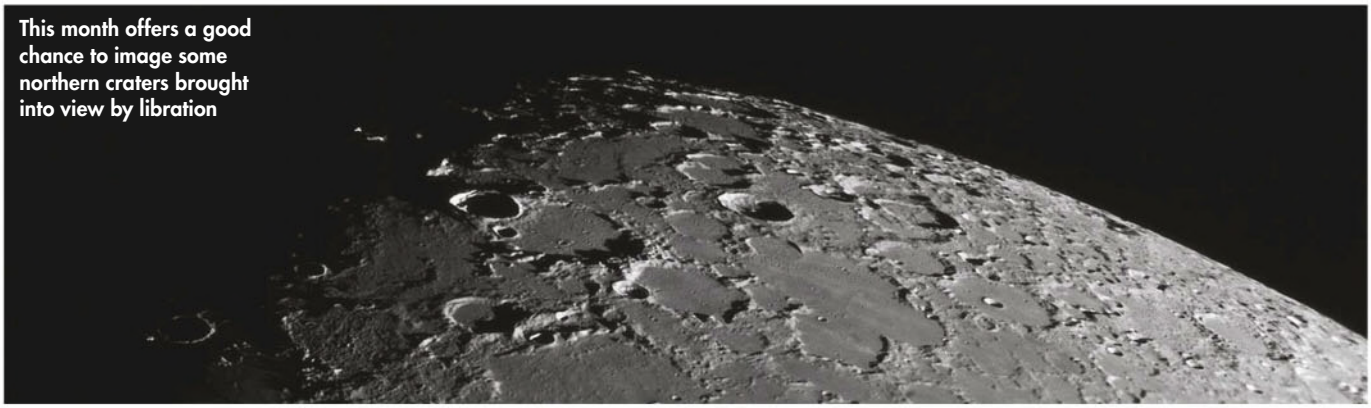
As it happens, at the end of November and into the start of December, the Moon's northern edge is favourably tilted towards us and illuminated. A similar situation occurs towards the end of December too, giving rise to a great opportunity to capture some of the Moon's tricky to see northern craters such as Peary, Byrd and Hermite.

Just to make things interesting, this month's imaging project will be to try and capture a dramatic mosaic image of this region using a high frame rate planetary camera. If you have the means to get a high magnification on the Moon, giving rise to a large image scale, there's good news here too, as the fuller lunar phases tend to occur when the Moon is high in the sky during the winter. Consequently, the Moon's disc should be a lot steadier than when it appears low down, close to the horizon.

If you want to try for something really adventurous and the weather plays ball, why not try and create a sequence of northern limb mosaics. These will really bring this region of the Moon alive allowing you to see just how amazing those dramatic shadows can be when they change from one night to the next.

So rather than see the Moon as a source of natural light pollution, embrace it this December. Decoding the heavily foreshortened multitudes of craters close to the northern limb will provide plenty of 'entertainment' when the clouds finally do appear. And, of course, this is bound to occur when the Moon's out of the way.

✉ Send your image to: hotshots@skyatnightmagazine.com



This month offers a good chance to image some northern craters brought into view by libration

ALL PICTURES: PETE LAWRENCE

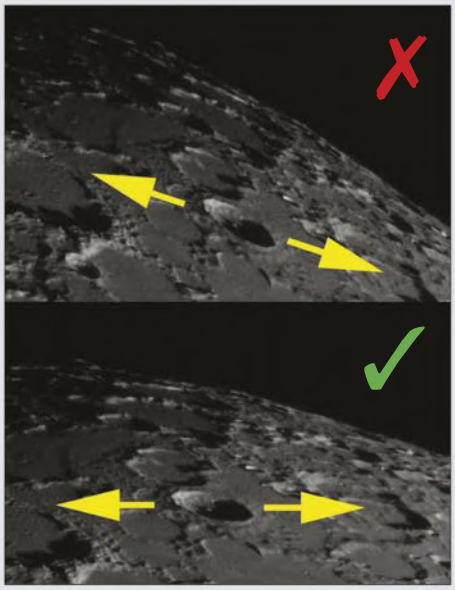
STEP-BY-STEP GUIDE

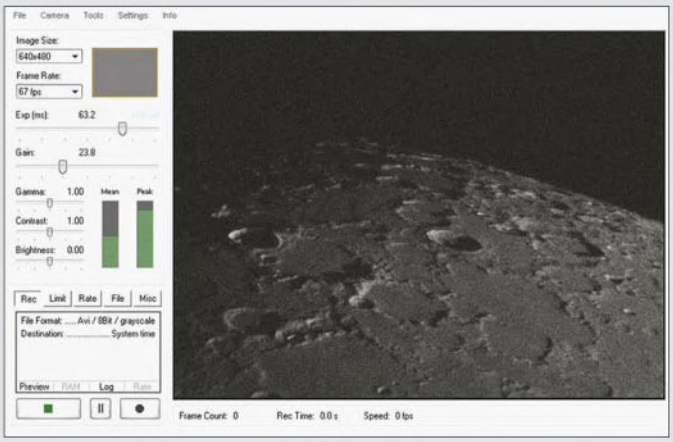
STEP 1

A monochrome high frame rate camera is best for lunar mosaics. A red or infrared-pass filter also helps to stabilise the seeing. A focal length greater than 1m is recommended. An optical amplifier, such as a Barlow lens, can be used to increase image scale. Aim for an effective focal ratio (amplifier power x telescope f/number) of f/15-f/25. Higher values may work if the seeing is really good.

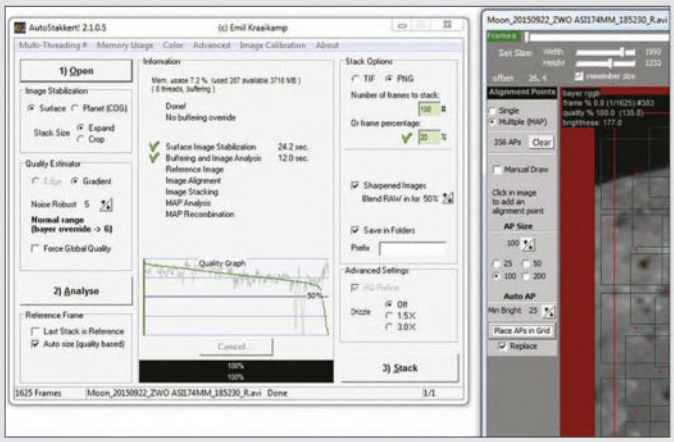
STEP 2

Place the northern edge of the Moon on screen and rough focus. Keeping hold of the camera, slightly slacken the eyepiece locking screws holding it in place. Slew the scope in RA, adjusting the orientation of the camera until features appear to move parallel to the top and bottom of the image frame. Once this has been achieved, lock the camera into the eyepiece holder securely.

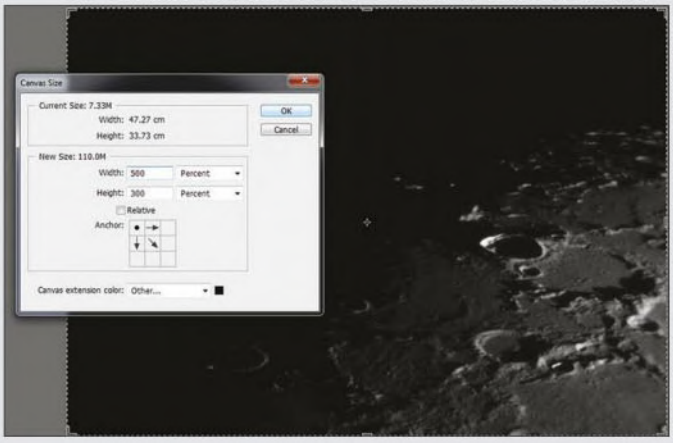




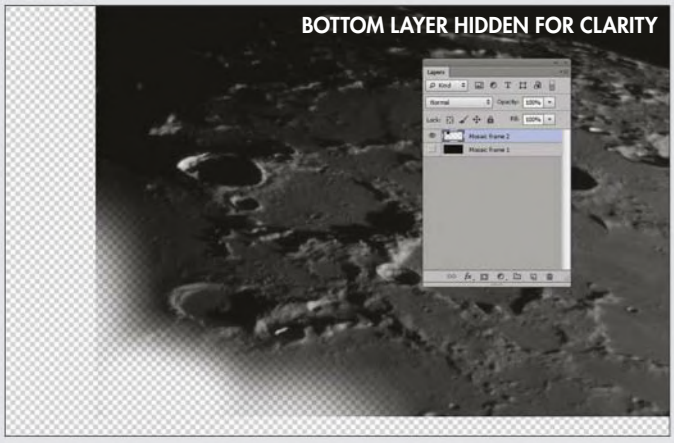
STEP 3 Move to a bright part of the mosaic region. Adjust your camera's gain and exposure values (keeping gain low) to get a saturation level of 80-90 per cent. Note these as your default values. Working in rows, take video sequences of around 800-1,000 frames overlapping by 25-30 per cent each time.



STEP 4 It helps to note a feature in each frame as a reference both for horizontal row frames and vertical row shifts. Make a rough sketch if that helps. Once done, drag all the videos into AutoStakkert. Select 'Surface', then Ctrl-click on a bright feature and press 'Analyse'. When done, select an AP size of 100 and click on 'Place APs in Grid'.



STEP 5 Set frame percentage to 10-20 per cent. Tick 'Sharpened images'. Finally, press the 'Stack' button. When the processing is complete, access the results folder. Load the first sharp version and crop any rough edges. Expand the canvas to accommodate the other frames. Load the next image and paste into the first image's canvas as a new layer.



STEP 6 In a graphics editor, drag the second image into approximate alignment with first image, nudging the upper image until toggling visibility shows no feature movement. Using a 10 per cent eraser, remove the sharp edges of the upper frame until it blends. Repeat for all frames and saving between layer additions. Finally, flatten and save.

THE WORLDS OF STAR WARS

A long time ago, a galaxy far, far away was filled with strange planets. **Elizabeth Pearson** *finds out if we could find any of them a little closer to home*

On 17 December, we return to a galaxy far, far away with the release of *Star Wars: The Force Awakens*. Over the course of the previous six films, we've been taken on a journey not only set aboard spaceships and battle stations, but across a host of mesmerising worlds. As we look deeper into our own Galaxy we are finding more and more strange new alien worlds; even in our own Solar System there are planets and moons very familiar to those we've already seen on screen.

ABOUT THE WRITER

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University.

The asteroid field of *The Empire Strikes Back* is nothing like the reality

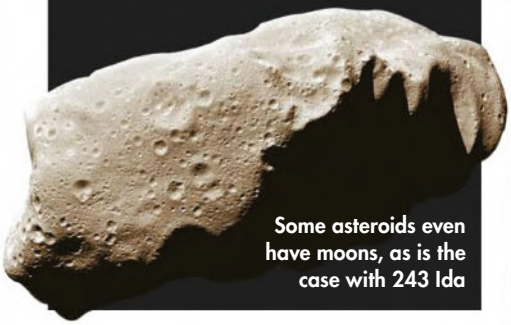
ASTEROID FIELD

In reality, dodging destruction is easy

To evade being shot down by Tie Fighters in *The Empire Strikes Back*, the Millennium Falcon hides out in an asteroid field. The asteroid field of the film is a densely packed place, filled with rocks that are constantly colliding and hitting the ship. But in reality, you'd have to be trying quite hard to even find an asteroid, let alone be struck by one.

If you landed the Millennium Falcon on a body in our Asteroid Belt the nearest one would be nearly 1 million km away: you'd need binoculars to see any evidence of it. The region hasn't always been this sparse though. It's estimated that the Asteroid Belt contained as much as 1,000 times more mass than it does now, but shortly after its formation collisions and gravitational disturbances would have thrown out most of the debris. Even if the belt still had its initial mass, it would be hundreds of thousands of kilometres between asteroids.

In other planetary systems more compact asteroid belts have been found, most within the snow line, the radius at which ice forms in a planetary disc. Beyond this giant planets tend to disperse the asteroids. Some asteroid belts have been found with as much as 25 times more mass than the one between Mars and Jupiter. This would still leave huge gaps between the space rocks, not the densely packed field depicted in the film. If a belt were that dense, the constant collisions between the rocks would soon grind them down into little more than dust.



Some asteroids even have moons, as is the case with 243 Ida

TATOOINE

A tale of two suns – and sometimes three or four

In *A New Hope*, Luke Skywalker looks to the horizon on his home planet of Tatooine at the twin suns setting in the distance. The desert world orbits not one, but two stars, locked in a binary pair.

In our own Galaxy several 'Tatooine' worlds have been found in the form of exoplanets orbiting two, three or even four stars, though so far all of these have been gas giants. No rocky worlds have been spotted yet.

"A close pair of stars acts much like a single star except that the planet will move back and forth a little as the stars swirl around each other," says Ben Bromley, professor of physics and astronomy at the University of Utah. "While this additional jostling is not a huge effect, it is enough to cause the building blocks of planets to crash into each other, leading to the destruction, not the growth of a planet." However when Bromley simulated the growth of planets in a debris disc surrounding a double star he found that they could form even under these unstable conditions.

◂ Multiple star systems with planets are not uncommon

"Despite the jostling, the building blocks can settle on orbits that ebb and flow with the stars' motion, and then they don't destroy themselves when they collide. In this way planets can grow."

If we can find a rocky world in a multi-star system, one day astronauts may be able to see a sunset like this.

BESPIN

Can you build a city in the clouds?

Cloud City, home of Lando Calrissian, floats in the atmosphere of a gas giant called Bespin in a layer that conveniently has the right pressure and oxygen level to support life. In reality gas giants are not so helpful when it comes to supporting cities. While there are layers that are around the atmospheric pressure of Earth, the atmosphere of gas giants is almost exclusively hydrogen and helium. So far no gas giant has been found with the level of oxygen needed to sustain human life.

But the idea of a floating city hovering above a planet, in the atmosphere, is not that far fetched. Zeppelin-inspired spacecraft have long been suggested as a way of exploring Venus, which has a thick atmosphere of carbon dioxide. As breathable air is predominantly made of the lighter gasses nitrogen and oxygen, an enclosed station would float just like a helium balloon in Earth's atmosphere.

NASA is exploring the idea of sending a balloon to Venus. The High Altitude Venus Operational Concept (HAVOC) mission would begin with unmanned probes and progress to sending craft to patrol the atmosphere, at first for 30 days but then increasing to a full-time manned presence above the planet. ▸

Could a zepellin-type craft be used to explore Venus?

Cloud City could not exist on any gas giant we know of

An AT-AT would likely freeze solid on any of the icy worlds that we know of

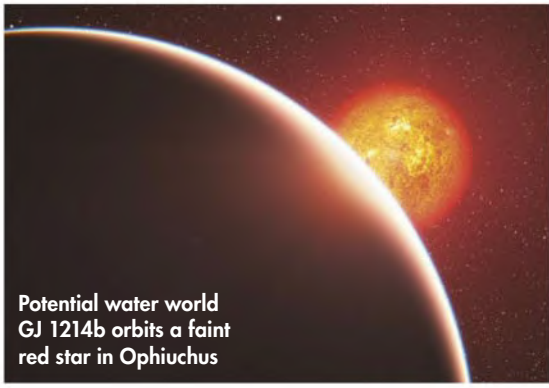
HOTH

A frozen wasteland is a great place to hide

An inhospitable world like the ice planet Hoth is the perfect place to hide a rebel base, as seen in the opening scenes of *The Empire Strikes Back*. Within our own Solar System there are many moons, such as Europa and Enceladus, that are completely encased in ice, but with no atmosphere and temperatures around –170°C it's unlikely anyone would be able to survive on these worlds, even with a Tauntaun to cut open and spend the night inside. However, a long time ago there was a planet in our Solar System that bore a striking resemblance to Hoth – our own Earth when it passed through the last ice age. As the temperature dropped, the world froze over and the bright white snow and ice that formed reflected more sunlight back into space, causing it to get even colder. Luckily for us a few volcanoes managed to poke through the ice, spewing carbon dioxide into the atmosphere. With no liquid water to soak it up, the gas formed an insulating layer, which trapped heat and melted the ice within a few thousand years. If there is a Hoth out there in the Universe, the chances are it won't remain inhospitable for long.

Earth was once like Hoth, in the time of the last ice age

Obi-Wan Kenobi spars with Jango Fett on Kamino, the world of endless oceans that birthed the clone army



Potential water world GJ 1214b orbits a faint red star in Ophiuchus

KAMINO

Ocean worlds could be found within our Galaxy

In *Attack of the Clones*, an army is secretly built and raised on the water-covered planet of Kamino. When considering the reality of a global ocean worlds there is one big issue – when we can't explain where the water on Earth came from, how could a planet form with enough to cover the entire surface?

"Earth actually has a lot more water than you can see," says Laura Schaefer from the Harvard-Smithsonian Center for Astrophysics. "We think the mantle of the Earth has at least the same amount as is on the surface, maybe even five to 10 times more. One way to get a totally ocean-covered planet is just to heat up the interior and drive all the water to the surface through volcanoes. Another is to form the planet further away from the central star, where the protoplanetary disc was colder and water could condense, so the planet just forms with more water in the first place."

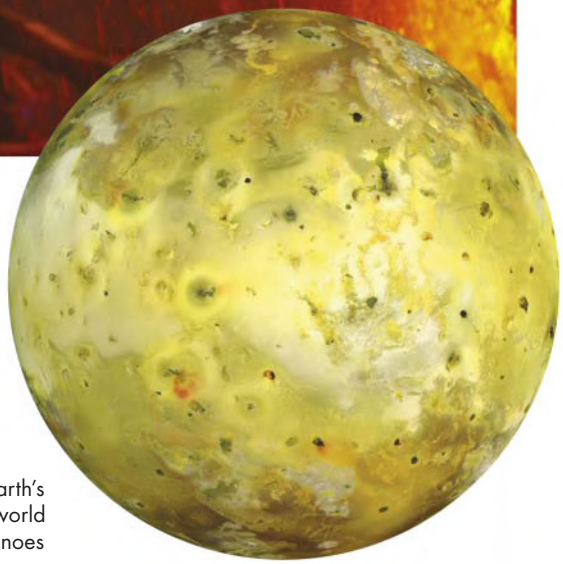
There have been suggestions that several exoplanets may be ocean worlds. GJ 1214b has 6.5 times the mass Earth, but a density more like water than rock, suggesting that it is 50 per cent water. Yet finding direct evidence of an ocean planet could be difficult.

"Water vapour tends to condense out into clouds on temperate planets and clouds will block our view of the surface, where most of the water would be," says Schaefer. "Another way is to look for the glint of sunlight on the water, but on a global scale."

The choking atmosphere of Mustafar is no place for a fight to the death

MUSTAFAR

A world torn apart by the force (of gravity)



► Io is by far the most volcanically active world in our neighbourhood

During the climax of *Return of the Sith*, Anakin Skywalker and his mentor Obi-Wan Kenobi have a grand face-off on the planet of Mustafar, fighting to the finish on a river of lava. In its early days, our Solar System was filled with rocky bodies being torn apart by intense volcanism, but these quickly cooled over the first few hundred million years. Not all worlds stayed sedate for long, however. When the orbits of two or more moons sync up in a resonance, the resulting gravitational tug of war pulls the internal rock or ice of a planet. The friction this creates causes a huge amount of heat to be generated. On ice moons such as Europa and Enceladus this process forms liquid oceans beneath the icy crust, but the effect is most impressive on Jupiter's rocky moon Io.

Despite only being about the size of Earth's Moon, Io is the most volcanically active world in the Solar System. It is covered in volcanoes and has lava flows as long as 300km. Depressions in the surface can even become filled with molten rock, creating lakes of lava that are then covered by a thin crust. However, Io's atmosphere is 90 per cent sulphur, and the air of any volcanic world would most likely be highly toxic, making lightsaber battles of good verses evil much more difficult.

A civilisation on the scale of Coruscant would almost certainly produce pollutants that we could detect

It may even be possible to detect light pollution from vast alien cities

CORUSCANT

Smog and city lights point the way to civilisation

At the centre of the Star Wars galaxy lies Coruscant, a planet covered in one huge metropolis and home of the Galactic Senate. If some civilisation within our own Galaxy had fully industrialised a planet, it could give humanity its best chance yet of finding intelligent life. Currently exoplanet research is concentrated on finding life from markers such as methane or oxygen in a planet's atmosphere, which would indicate the presence of basic life, but advanced civilisations would leave signs that could also be detected.

"We could detect industrial civilisations through their pollution of the planet's atmosphere with artificial chemicals that do not form spontaneously in nature," says Avi Loeb, chair of the Astronomy department of Harvard University. "To be detectable, industrial pollution by CFC molecules needs to be at least 10 times larger than currently found on Earth."

Urbanisation on the scale of Coruscant would have dramatically changed the planet's atmosphere. It's likely that any civilisation would take similar steps, as humans have done, to reduce emissions of most harmful atmospheric pollutants. However one area of pollution that has generally gone unchecked, as any city astronomer can attest, is light pollution. Though it would be difficult to pick out the signal against the background starlight, the light from our street lamps could be travelling much further than we think.

"It turns out that existing telescopes could detect the light from a city like Tokyo all the way to the edge of the Solar System," says Loeb.

A RECORD YEAR FOR SPACE

Dave Hawksett, science consultant for Guinness World Records, gives his take on why 2015 has been a superlative year for space exploration

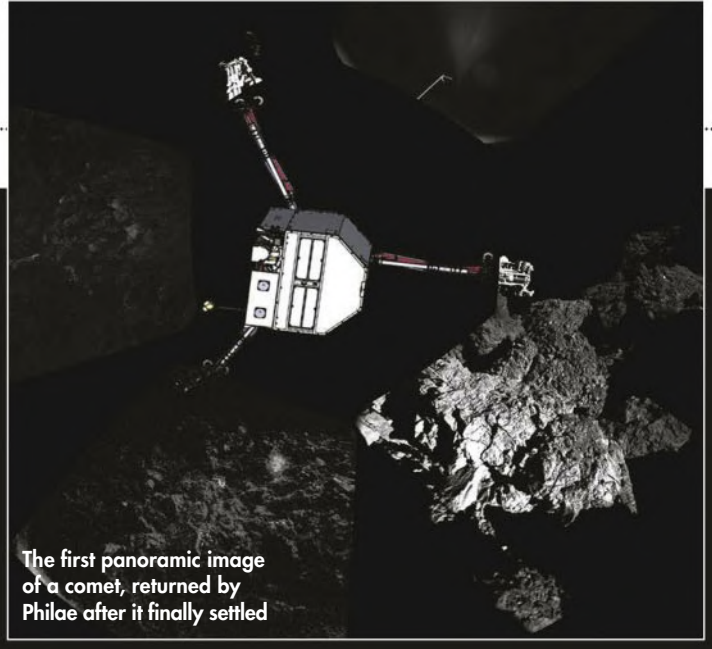
There was a time during the mid 1990s when it seemed that Solar System exploration was in the doldrums. Magellan had finished its mission at Venus, while Mars Observer and Mars 96 had both failed. At NASA's Jet Propulsion Laboratory, the Galileo team were still trying to fix a stuck main antenna on the spacecraft as it made its way to Jupiter; the command to unfurl its umbrella-like dish had been sent around 100,000 times.

But fast-forward two decades and just look where we are now: until recently we had spacecraft orbiting Mercury, Venus, Earth, Mars and Saturn, and now we are also orbiting a comet, a dwarf planet – Ceres – and have visited Pluto. This means we have carried out an initial survey of every major body in our planetary system.

Of course, it's not just in the Solar System that superlatives are being toppled and firsts are being set. This is happening across the field of astronomy. So although we concentrate on the Solar System on the following pages, there are a few trips farther out into the cosmos.

ABOUT THE WRITER

Dave Hawksett is an amateur astronomer and the contributing science consultant for Guinness World Records



The first panoramic image of a comet, returned by Philae after it finally settled

FIRST ORBIT AND LANDING ON A COMET

After Philae's landing last year, Rosetta continues to set records

Where does one begin with accolades for Rosetta? First to drop a lander on a comet, first to orbit a comet, and currently establishing new records for the longest time to orbit a comet. On its long journey Rosetta established the record for the most distant solar powered spacecraft, which it will hold until Juno is well into its orbital tour of Jupiter in 2017. As it has followed 67P/Churyumov-Gerasimenko through perihelion this year, it observed heightened activity closer than ever before. The Open University's Colin Pillinger was a major driving force behind this ambitious mission but he tragically never got to see its success having passed away in May last year, just months before Rosetta entered 67P's orbit.

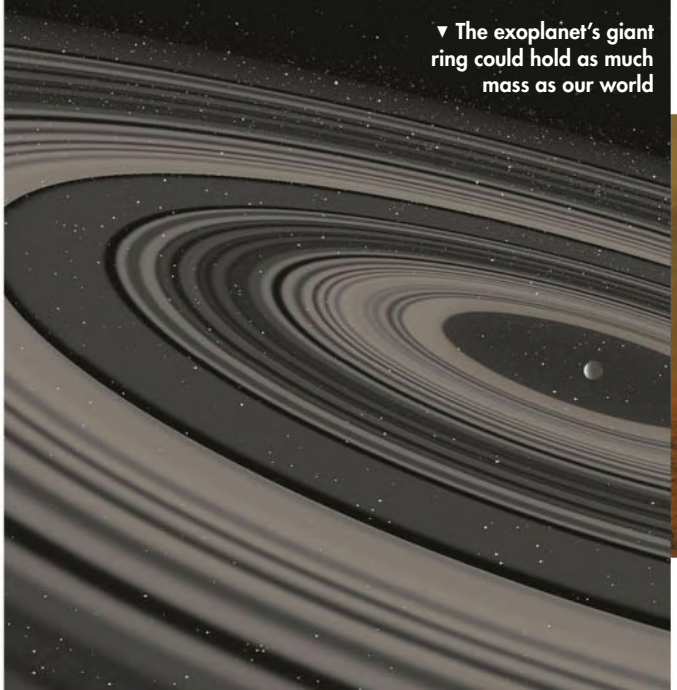
▲ One of 67P's great surprises is its 'duck-like' shape, a narrow 'neck' joining the two lobes

BIGGEST EVER PLANET RING SYSTEM FOUND

In January astronomers found an exoplanet with gargantuan rings

This year a new analysis on what has been termed 'Saturn on steroids' was published. Exoplanet J1047b has a ring system nearly 120 million km across, dwarfing that of Saturn. This is now the largest ring system we are aware of and it probably has a mass of around one Earth. The new results also show 37 rings as well as gaps which hint at the existence of plenty of satellites. Whether or not this will prove to be the largest planetary ring system remains to be seen, as J1047b could be a brown dwarf star rather than a large gas giant.

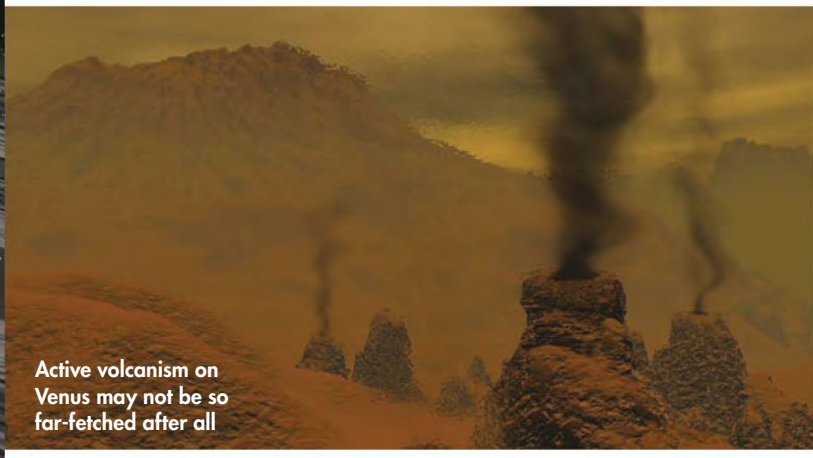
▼ The exoplanet's giant ring could hold as much mass as our world



DIRECT EVIDENCE OF VOLCANISM ON VENUS

In January Venus Express observed hot spots in its final manoeuvre

It looks like the jury is no longer out on active volcanism on Venus. More than 20 years after Magellan plunged into the Venusian atmosphere, ESA's Venus Express met the same fate. But its last manoeuvre bestowed some critical observations of a region known as the Ganiki Chasma rift zone, showing transient hot spots, one of which was estimated at around 1km^2 in size. At 830°C, it is much hotter than the average surface temperature. Whether or not Venus is currently volcanically active has been a hot topic for decades, and in some cases the debate has split the planetary science community. If JAXA's Akatsuki spacecraft fails to reach Venus orbit on its second attempt in December 2015, we will have to wait until at least 2017-2018 for the next mission to be launched to Earth's evil twin, by the Indian Space Resource Organisation. ▸

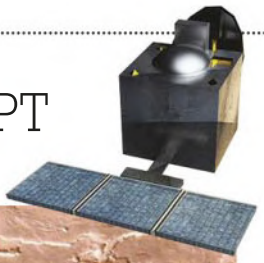


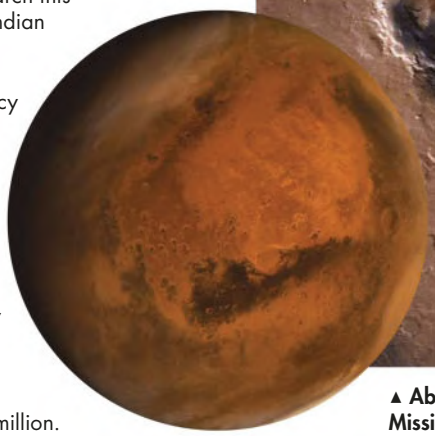
Active volcanism on Venus may not be so far-fetched after all

INDIA ACHIEVES MARS ORBIT ON FIRST ATTEMPT

In March India became the fourth nation to reach Mars, and the first to do it in one

The Great Galactic Ghoul – that fictional monster that allegedly chews up Mars missions – has been thwarted for the first time. India's Mars Orbiter Mission, launched on 5 November 2013, successfully entered Martian orbit on 24 September 2014 and completed its initial mission in March this year. This makes the Indian Space Research Organisation (ISRO) the fourth space agency to reach Mars but, considering how many Mars missions have failed, it is even more impressive that ISRO has become the first agency to reach Mars on its very first attempt. As if that was not enough, the mission cost has been estimated at just $73 million.





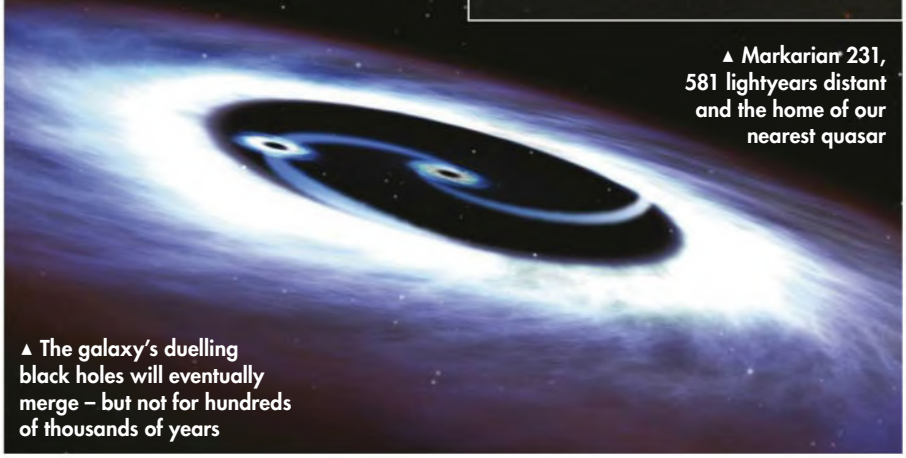
▲ **Above: Curiosity's landing site, Gale Crater, as imaged by India's Mars Orbiter Mission; left: the orbiter also snapped this full disc image of Mars on its arrival**

THE CLOSEST QUASAR

In August Hubble observed not one but two black holes powering our nearest quasar

To be 'under one's nose' at a distance of 581 million lightyears, you can only really be a quasar. The closest to us of these rather alarming objects is within a galaxy designated Markarian 231, which was discovered in 1969 in the constellation of Ursa Major. This year astronomers using the Hubble Space Telescope revealed that the centre of this Seyfert galaxy is powered by not one but two black holes, weighing in at 150 million and four million solar masses respectively. The asymmetric nature of Markarian 231, along with long tails of young stars, points to a probable merger with a smaller galaxy, and it is likely that the smaller black hole came from this. With an orbital period of just 1.2 years, these two monsters will collide and merge in the next few hundred thousand years.

▲ **Markarian 231, 581 lightyears distant and the home of our nearest quasar**

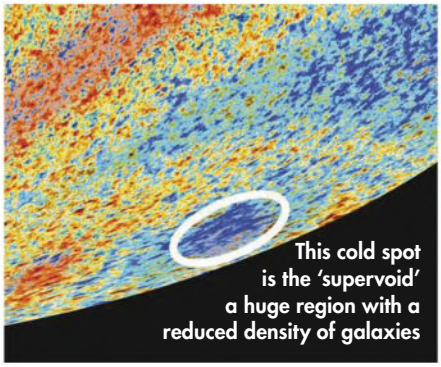


▲ **The galaxy's duelling black holes will eventually merge – but not for hundreds of thousands of years**

LARGEST VOID IN THE UNIVERSE

In April astronomers picked up an immense area of the cosmos that was 'empty'

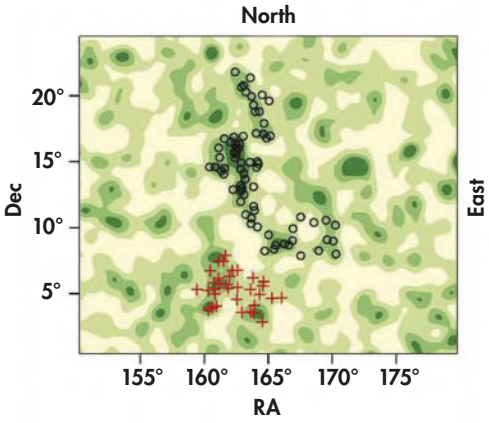
When Edwin Hubble discovered the whole 'rest of the Universe', it was too soon for conspiracy theorists to strike. Imagine, then, if we only discovered that there were other galaxies in the 1960s? That's exactly what would have happened if we lived in the centre of the Boötes Void, which used to be the largest known 'void' in the Universe. But announced this year was the analysis of a 'supervoid' 1.8 billion lightyears across, dwarfing the Boötes Void. Of course 'void' is a misnomer: it is really a region of space that is 'underdense' compared to everywhere else. In fact, this region is missing some 10,000 galaxies. This record is likely to be broken in due course, but only for a limited number of times. The Universe is only large enough to contain a handful of voids of this scale.



This cold spot is the 'supervoid' a huge region with a reduced density of galaxies

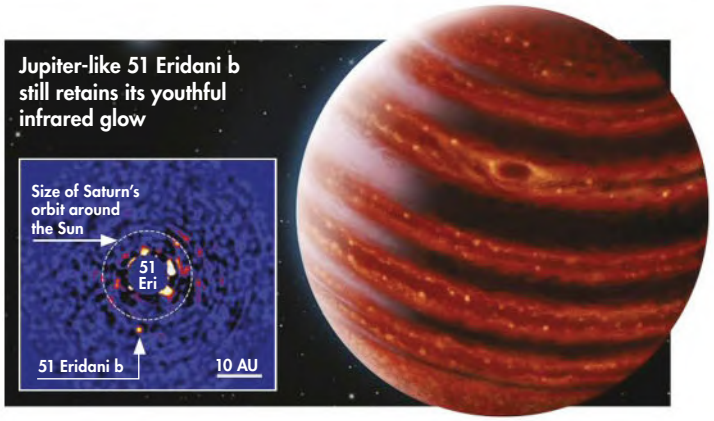
BIGGEST STRUCTURE IN THE UNIVERSE DISCOVERED

In July quasars gave away the location of a giant galactic ring inferred from gamma-ray bursts



▲ **The black circles mark the giant gathering of quasars; the red crosses a smaller group**

Gone are the good old days when the biggest structure in the Universe was something you could see, with a formation like a stick man at its centre. While not as big as the current holder, the Great GRB Wall, a newly discovered structure announced this summer looks to be the biggest regularly shaped structure so far: a giant ring of galaxies 5.6 billion lightyears across and around nine billion lightyears away. But it was not discovered by mapping galaxies; instead its existence is inferred from the observations of nine gamma-ray bursts in a ring pattern across a region of sky 36° across. Gamma-ray bursts are the most powerful events in the Universe and they need host galaxies. The chance that these bursts happened randomly and do not imply a giant structure is only one in 20,000; those are pretty good odds!

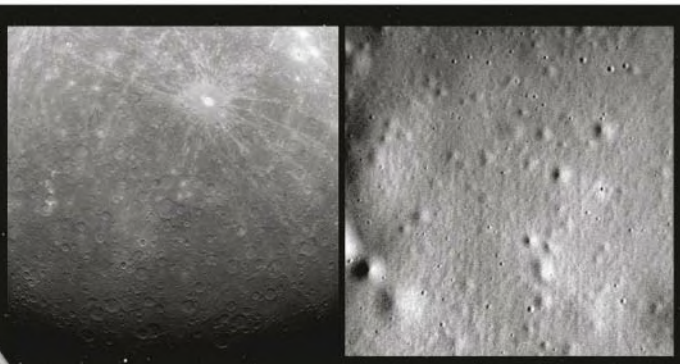


SMALLEST EXOPLANET DIRECTLY IMAGED

In August astronomers directly observed an alien world 1.9 billion km away

The rapidly growing catalogue of known exoplanets continues to challenge theories of planetary system formation. This summer astronomers announced the discovery of 51 Eridani b, which had been found using the Gemini Planet Imager on the Gemini South Telescope in Chile. Categorised as a young Jupiter, it orbits 51 Eridani at around 13 astronomical units and still glows from the heat of its formation, only around 20 million years ago. While not the most exotic exoplanet found so far, what makes this so special is being able to clearly see the planet itself, rather than its shadow or its gravitational pull on its star.

▼ **Messenger mapped the planet's entire surface over the course of its life**



▲ **The first image captured by Messenger, taken on 18 March 2011 (left), and the last one, taken on 30 April 2015 (right)**

LONGEST TIME ORBITING MERCURY

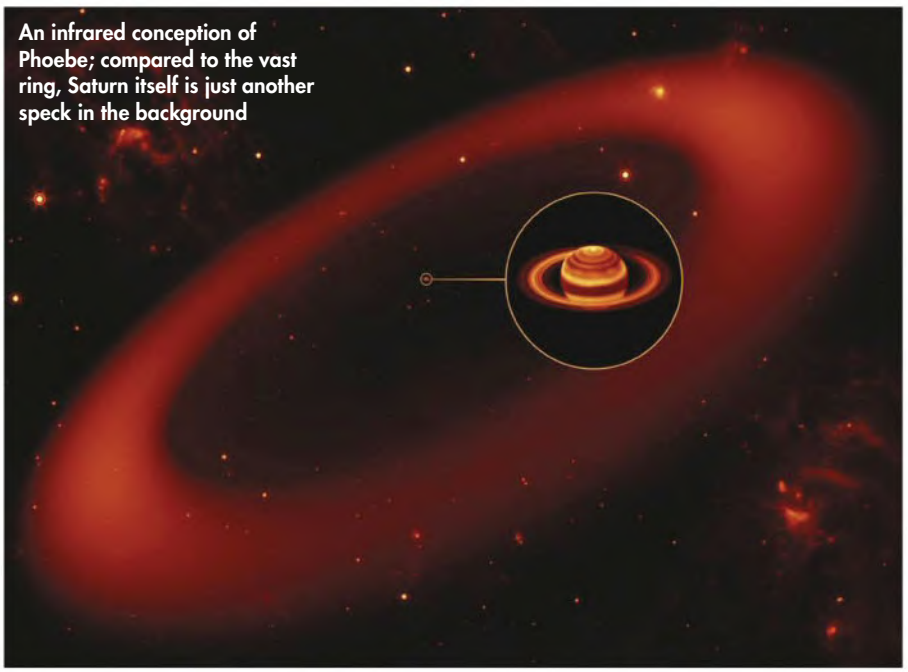
In April Messenger's time in orbit came to an impactful end

The best word of the year has to be 'lithobraking', which describes Mercury orbiter Messenger's final moment as it deorbited and impacted on the surface, after becoming the first spacecraft to orbit the innermost planet. For four years, one month and 12 days it mapped 100 per cent of Mercury as well as finding water ice at its north pole. Nine years from now the ESA/JAXA BepiColombo spacecraft will arrive at Mercury, and its two orbiters will start their task to beat Messenger's endurance record. It only has a planned duration of a year once it reaches the planet, but so did Messenger. ▸

BIGGEST RING IN SOLAR SYSTEM

In June, Saturn's outermost ring was extensively characterised

As Cassini begins its 'long goodbye' series of observations before heading to a fiery destruction in Saturn's atmosphere in 2017, we should appreciate the mission's treasure trove of data and images. They really do fulfil imaging team leader Carolyn Porco's promise to capture the beauty as well as the science of the Saturnian system. However Cassini's work at Saturn has been complemented by other spacecraft and this year the outermost ring, first discovered in 2009, was found to be even larger than first thought. Infrared images from NASA's WISE spacecraft show that the tenuous ring – Phoebe – extends 6 million-16.2 million km from Saturn.



An infrared conception of Phoebe; compared to the vast ring, Saturn itself is just another speck in the background

NASA/JPL-CALTECH/KECK, NASA/JHUAPL/SWRI X 4

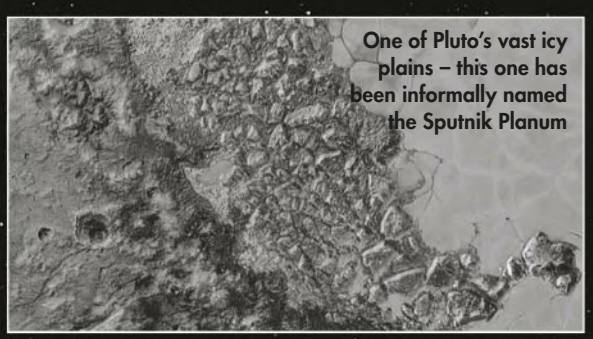
False colour images of Pluto and its moon Charon revealed unimaginable surface features

A mere 15 minutes after its closest approach to Pluto, New Horizons captured this image of the Sun setting on the dwarf planet

FIRST TO REACH PLUTO

In July New Horizons made it to the Solar System's outer reaches

As each new detailed New Horizons image gets released after July's Pluto flyby, it just serves to ramp up the anticipation for the next ones. Need I say more than nitrogen glaciers and layered atmosphere! Being the first to reach Pluto has to be the most significant record set by this epic mission, but it could have been the first spacecraft to impact an unknown moon. As more data and images are downloaded from the spacecraft there should be plenty of records for features on the surfaces of Pluto and Charon. However, it is possible this mission's biggest legacy will be to reignite the debate on Pluto's status in the Solar System. Mercury's title as smallest planet in the Solar System may only be temporary.



One of Pluto's vast icy plains – this one has been informally named the Sputnik Planum

ASTRONOMERS' Gift Guide

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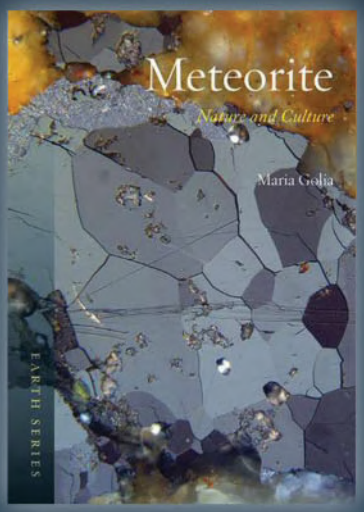

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By Maria Golia

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'In this well-researched and copiously-illustrated book the author looks back in time to discover how the arrival of these celestial visitors induced a sense of awe and wonder in our ancestors' – 'Book of the Month', *BBC Sky at Night Magazine*

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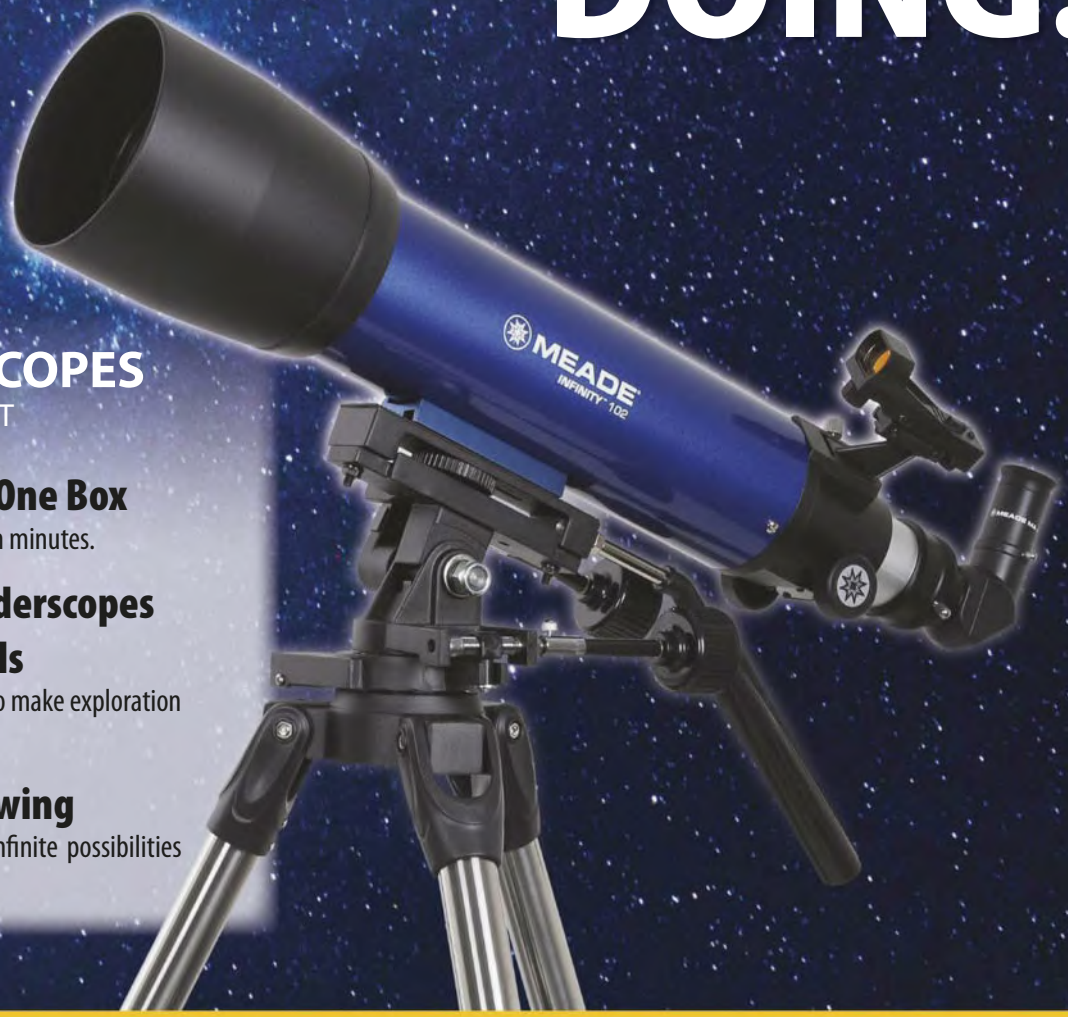

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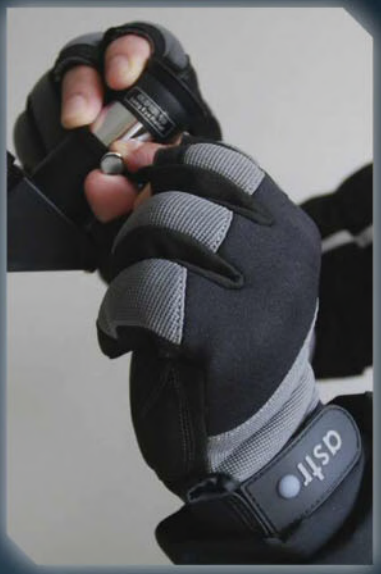

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Jupiter, Mars, Saturn and Venus imaged through the author's Dobsonian scopes

CAPTURING PLANETS THE DOBSONIAN WAY

Dobsonian scopes can be adapted for effective planetary imaging – **Martin Lewis** explains how

Dobsonian mounted Newtonian telescopes enjoy great popularity due to their ease of use and tremendous value for money, giving the largest aperture possible for the lowest cost.

The Newtonian design is simple. Being a pure reflector there are no issues with colour fringing, and the central obstruction also tends to be smaller than in other reflectors such as Schmidt-Cassegrains. This means that large aperture and low-cost Dobsonians can often yield great planetary images. Their big aperture makes the images bright and contrasted, and provides extra resolving power to see surface detail.

The Dobsonian mount was intended to be a simple push-to altaz mount for visual observing, and by far and away the majority of Dobsonian telescopes are operated like this. However, some astronomers have found ways of using their Dobsonian reflectors to take great photos of the planets by recording video and then stacking individual frames using software such as RegiStax or Autostakkert!, reducing the blurring effects of the atmosphere. Sharpened in a graphics editor, the final image shows a wealth of surface detail.

MARTIN LEWIS X 4, PAUL WHITFIELD

Drift or driven

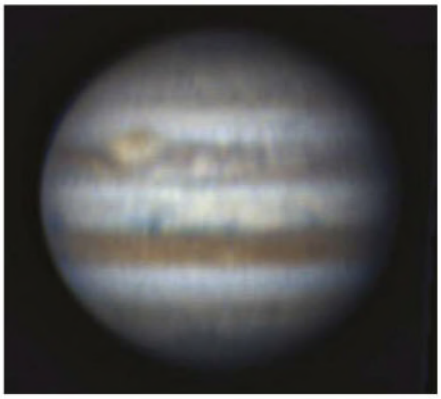
The simplest way of capturing videos is the drift method, which requires no driven mount. Just capture multiple short video sequences as the planet drifts through the field and then combine the videos into one image. Each second a planet drifts about 15 arcseconds, so exposures of 30 milliseconds will lead to drift smearing of only about 0.5 arcseconds, similar to the level of detail you would see on a good night.

The true window over which you can gather videos is also limited by rotational smearing. The following guide shows how long you can image the planets before rotational smearing of about 1 arcsecond becomes evident:

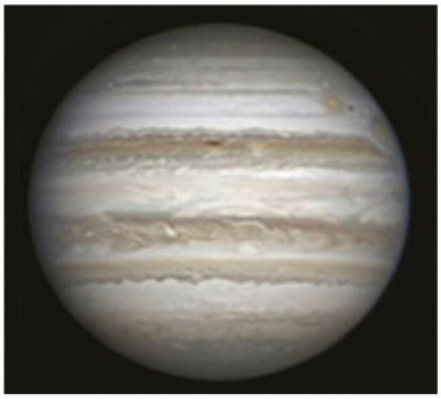
- ▶ Venus: no real limit over one session
- ▶ Mars: five minutes
- ▶ Jupiter: five minutes
- ▶ Saturn: 10 minutes

You'll probably need to use a Barlow lens to enlarge the planet's image, and the best magnification Barlow depends on lots of factors. Too low and you lose detail by undersampling, but too high and you will have to manually reposition your scope frequently. Start with a power that gives a focal ratio of f/10 and experiment around there. If you can, use a camera with a bigger chip to maximise the percentage of time that the planet is in the frame.

Although you can get reasonably pleasing photos with the drift method, driven methods really let you pull out significant planetary detail. With a driven ▸



▲ **The gas giant Jupiter imaged with a 8.7-inch Dobsonian using the drift method**



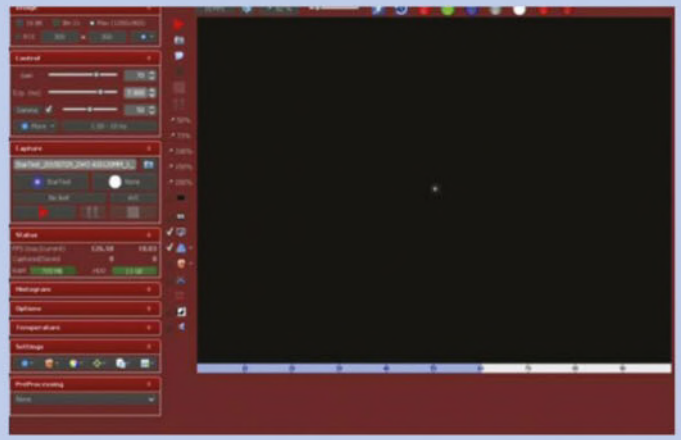
▲ **Jupiter imaged with the same scope but mounted on a driven equatorial platform**

▸ scope you eliminate drift smearing and can increase the magnification to boost the image scale without worrying about getting very short drift runs. Also, you can gather more frames to help reduce image noise because you don't need to waste time repeatedly moving the scope to the start of the drift run.

But if Dobsonians are supposed to be push-to scopes, how do you get them to track a planet? One method is to fit a Go-To drive system and the other is to place the scope on an equatorial platform. Neither of these methods would probably be good enough for long exposure deep-sky photos, but because planetary images are generally a few tens of milliseconds long, and because of the frame to frame alignment capability of the stacking programs, both types are good enough for planetary imaging.

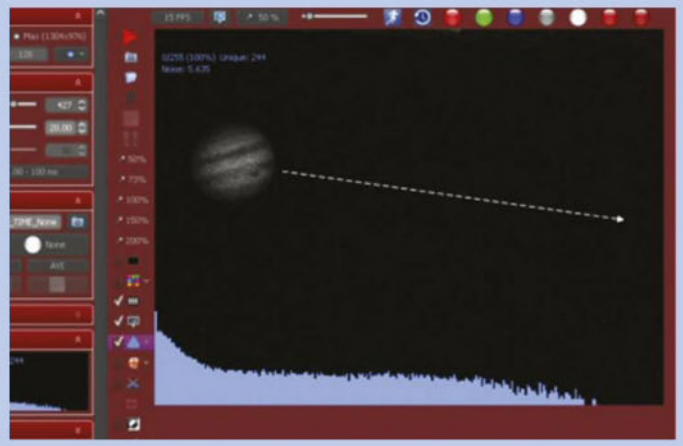
Go-Tos generally use friction drives on the altitude and azimuth axes, which can be engaged or disengaged to change between 'go-to' and 'push-to'. Equipped like this, a Dobsonian should be able to keep the planet in frame and allow you to record videos to process into detailed pictures later. The Go-To will make finding your target easy and you should

CAPTURE IMAGES WITH THE DRIFT METHOD



STEP 1

Set up your scope and allow it to cool to reduce thermal currents, then collimate as normal. Connect a digital video camera to the telescope and, looking at your laptop, focus critically on a star. Polaris is a good choice for the star as it won't move while you are focusing.

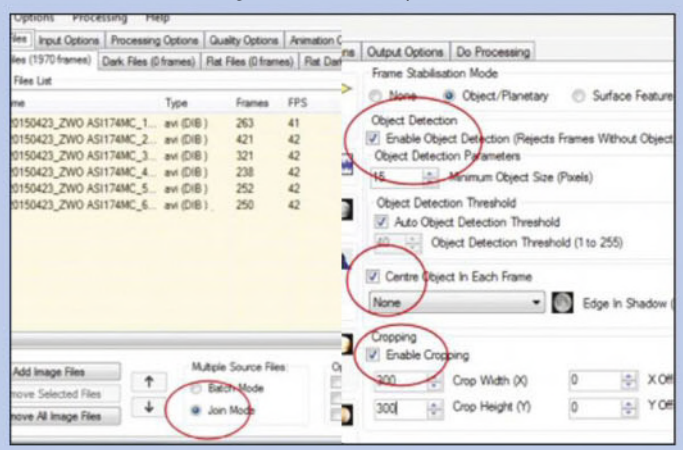


STEP 2

Line up your finderscope so that Polaris is near the middle of the camera frame. Align on the planet and check the chosen exposure settings. Planet brightness should be about 70-80 per cent of the saturation level and the gain about 50-75 per cent of maximum.

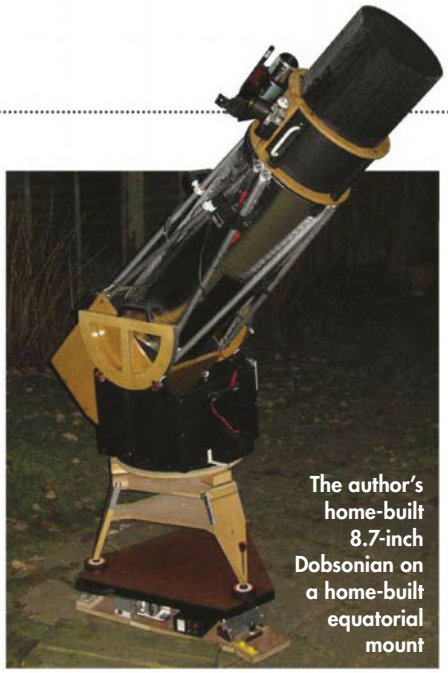
STEP 3

Reposition the scope so the finder cross-wires are just ahead of the planet. As soon as the planet enters the camera frame, hit record. Keep recording until the planet drifts out of the frame. Quickly repeat. Keep going until you have gone outside the time window for your target.



STEP 4

Join your videos together using PIPP's (https://sites.google.com/site/astropipp/) 'Join' mode. Use the 'Object Detection' and 'Centre and Crop' functions to keep the planet centred and eliminate the empty frames. Process this output video in RegiStax or Autostakkert! to finish.



The author's home-built 8.7-inch Dobsonian on a home-built equatorial mount

be able to compensate for any inaccuracies by using the motors manually to recentre the planet. Because you are using an altaz system, however, in time the planet will rotate relative to the frame of the camera. This is less of a problem for planets than for deep-sky imaging, because the videos tend to just be a few minutes long, limiting the amount of rotation during a video. Over the course of 10 or 20 minutes, however, the field rotation could become noticeable if combining images from different videos. Fortunately the very useful derotate function in WinJupos (http://jupos.org/gh/download.htm) will not only compensate for the rotation of the planet on its axis, but also for orientational drift due to this field rotation effect.

The equatorial approach

Mounting your Dobsonian on an equatorial platform is your second option and gives your scope true equatorial movement for an hour or so before the platform needs to be repositioned back to the start. Like the Go-To drive method, it maintains the low, stable centre of gravity of the Dobsonian design. With it you can continue to use the normal push-to altaz movements of the Dobsonian mount that are so much more in tune with the human frame of reference, but as soon as you have found the target it stays put in field as the equatorial platform tracks it. An equatorial platform can be moved between scopes and even used to place a normal camera tripod on to turn your DSLR into a fully tracked camera.

Commercial equatorial platforms are available from a number of different suppliers and generally are made for a specific latitude. For planetary imaging, absolute tracking accuracy from the drive system is not essential but it is useful to be able to adjust the drive speed slightly to keep the target in the field. Some platforms also have a screw jack on the southern end to help move the object up and down in the field.

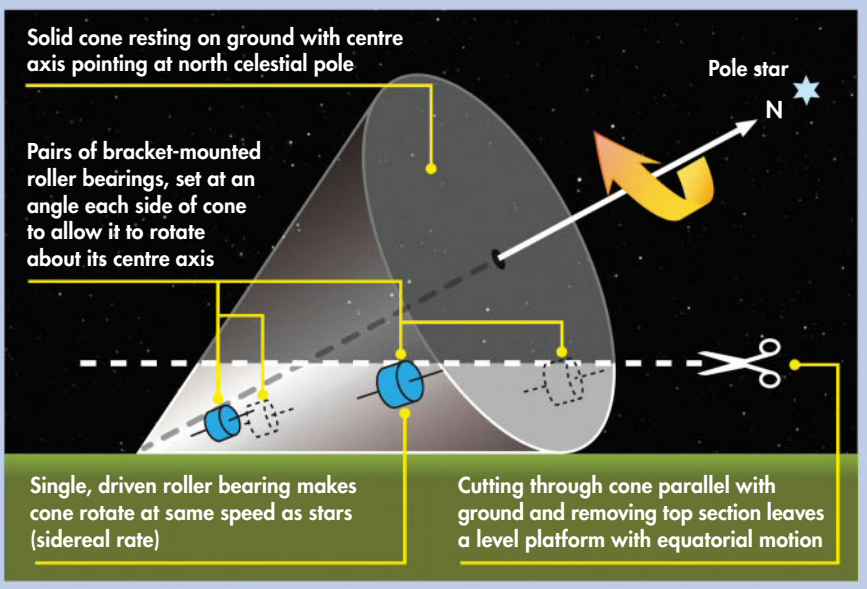
One of the most important characteristics of a telescope drive system, if you want the highest resolution images, is that vibration should have an insignificant effect on the image. Equatorial platforms are prone to such vibration as they often use stepper motors as the main drive. You may not see signs of this vibration in normal use at the eyepiece but if it is there it will prevent you from achieving full high-resolution imaging. A simple test involves inserting a high power eyepiece and checking the smoothness of the twisted track of a bright star when you firmly tap the eyepiece to shake the scope. Vibration will be seen as a saw-tooth on the smooth path.

EQUATORIAL PLATFORMS

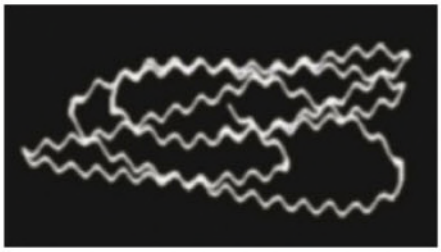
How this setup tracks like a German equatorial mount

Understanding how an equatorial platform works can be confusing – they look so different from most other types of equatorial mount and do not seem to have an obvious rotation axis. To help with understanding imagine this:

▶ There is a large solid cone on the ground with its centre axis pointing at the North Celestial Pole.
▶ Two pairs of roller bearings are fitted on brackets running against the outside surface of the cone, one pair near the narrow end and the other pair near the wide end, angled so their axes point towards the apex of the cone. These should restrict the cone to rotating about its axis.
▶ One roller is driven so the cone rotates to follow the stars.
▶ Cut through the cone parallel with the ground and dispose of the top section. The flat platform that's left will have equatorial tracking properties.
▶ Anything placed on this platform will automatically follow the stars as it will have an axis pointing at the Pole Star and be rotating at the same rate as the night sky.



▲ A tapped eyepiece at high power; the star path is smooth as it settles down again



▲ If the star path shows a saw-tooth pattern, it indicates that drive vibration is present

ABOUT THE WRITER

Martin Lewis is a keen astronomer. As a regular *First Light* reviewer, he has in-depth knowledge of observing with all sorts of equipment.

MARTIN LEWIS X 9

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The Guide

PART 2

Understanding optical aberrations

With **Steve Richards**

Three more common problems, plus tips on how to deal with them

In part one (October 2015) we examined the three most common optical aberrations that affect amateur telescopes, but there are several more that you should be aware of. In this second part we will be looking at another trio – pinched optics, vignetting and astigmatism. There are of course more aberrations still, but these are somewhat rarer. And although we won't be covering collimation in this article, it is important to ensure that your telescope is accurately collimated in accordance with the manufacturer's instructions to ensure that you achieve the best results from its use.

Steve Richards is a keen astro imager and astronomy equipment expert

A typical example of vignetting, taken through a 3-inch refractor

△ VIGNETTING

Affects: All telescope designs

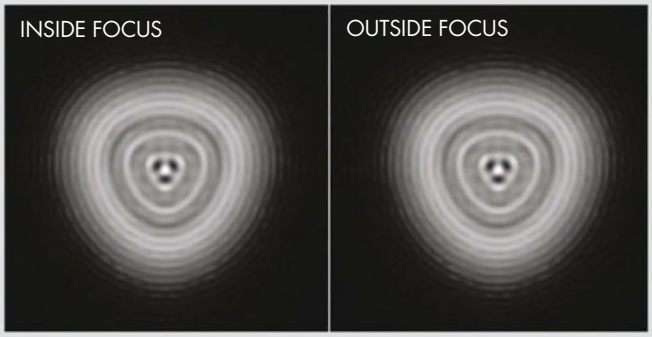
Most optical systems don't fully illuminate the field of an eyepiece or the surface of larger camera sensors, resulting in stars of equal magnitude appearing dimmer at the edges of the field than at the centre. This phenomenon is known as vignetting. It is particularly noticeable in deep-sky images, where the centre of the field of view can appear markedly brighter than the periphery.

Typical causes include the poor positioning of baffles within a refractor, a secondary mirror that is too small to fully intercept the light cone from the primary mirror in a Newtonian reflector or the use of narrow adaptor tubes to attach the eyepiece or camera to the telescope.

Catadioptric scopes like Schmidt-Cassegrains, Maksutov-Cassegrains or Ritchey-Chrétiens require a baffle tube to prevent light from the front of the telescope falling directly onto the focal plane before reflection from the primary mirror and this can cause vignetting. It is important that focus tubes are of large enough diameter to avoid obstructing the light cone and the restrictive visual back on many Schmidt-Cassegrains can be a particular problem.

ALL PICTURES: STEVE RICHARDS

PINCHED OPTICS



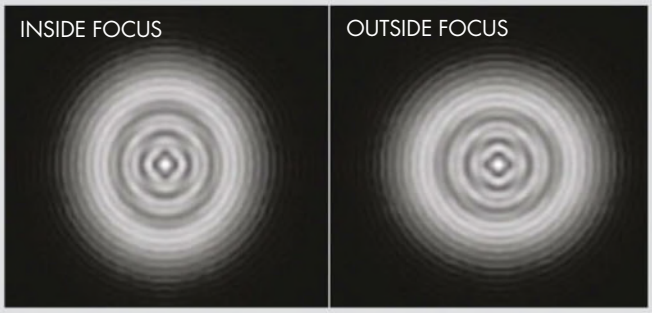
▲ A simulated Airy disk showing pinched optics

Affects: All telescope designs

In a refractor, the individual lens elements are held in place within a cradle called a lens cell; in a reflector, the primary mirror is held in place by a series of small clips that hold the mirror in an adjustable carrier. The lens cell or mirror clips must be adjusted to hold the optical elements firmly in position at all angles of elevation, but not so tightly as to cause a tiny compression of the optical surface. Failure to get this very fine adjustment correctly set at the factory can result in the mirror being slightly deformed resulting in the optics being 'pinched'.

Images of stars captured through a scope suffering from pinched optics show a clear distortion giving bright stars a triangular appearance sometimes with small flares emanating from the three 'corners'. Temperature can have a big effect on this aberration with a telescope, especially a refractor, having no apparent problem until the temperature drops and the various components start to contract.

ASTIGMATISM



▲ Another simulated Airy disk, this time revealing astigmatism

Affects: Refractors and Ritchey-Chrétiens

The optical path through a telescope has two planes, the tangential plane and the sagittal plane. These two planes are at right angles to one another. To visualise this, imagine that you are looking at the side of the light cone as it leaves the telescope lens or is reflected from the telescope's mirror on its way to the focal plane. This triangular shape is the tangential plane. Now imagine looking down on the light cone from above the telescope. The triangular shape of this light cone is the sagittal plane.

These two planes define the focal length of the telescope and they should be identical in length to ensure that their focal planes coincide exactly. Any deformity in the shape of the lens or mirror can result in the focal planes being at slightly different points producing distorted star shapes. A defocused star test will show this distortion in the Airy disk.

FIXING ABERRATIONS

Unfortunately, not all aberrations can be eradicated: some are caused by manufacturing or assembly errors, others are simply a limitation in the telescope's design. Of the six we have looked at over the two parts, chromatic aberration and astigmatism are unlikely to be fixable at home. However, the other four can be tackled successfully.

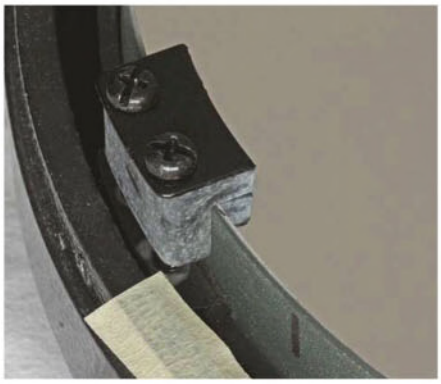
Field curvature can be corrected by the use of an external field flattener, available in two designs, one that flattens only and a second type that also reduces the apparent focal length. These are very popular with refractor users.

Coma can be removed by the use of a coma corrector. These have the added advantage of increasing the available backfocus, which is in short supply with Newtonian reflectors.

Pinched optics can be corrected by slackening off the retaining clips on the primary mirror so that they just hold the mirror in place, or by careful adjustment of the lens cell in a refractor. The latter may be better carried out by a professional. Finally, vignetting can be dealt with through calibration with flat frames during post processing – this can make a huge difference to your images.

▲ A flattener can be used to tackle field curvature, which can cause blurry stars

▲ Coma correctors help to counter comet shaped stars – plus, they increase backfocus



▲ If your views appear to be 'pinched', loosening the retaining clips may help

How to
Clean your DSLR sensor

With **Ian Evenden**

Remove dust spots from your images at the source

▲ **The sensor of a DSLR camera is tucked behind the reflex mirror – as such, the camera has to be switched on while you clean it**

Dust build-up on a camera sensor can lead to dark blobs on your DSLR images, which in the case of astronomical photos can obscure detail and darken the brightest parts of a planet or nebula – a particularly galling scenario when you've gone to so much trouble to capture that light in the first place. While these artefacts can often be removed in image-editing software with cloning or healing tools, it's best to treat the problem at its source. That means taking the plunge and cleaning the camera's sensor.

The sensor of a DSLR camera hides behind a reflex mirror, which deflects the light coming from the lens up into the prism that forms the viewfinder. It flips out of the way when an exposure is made or the camera is used in live view mode, and thus provides a certain degree of dust-proofing, but the tiny motes can and will still get in. The air displacement caused by zoom lenses moving their elements around, for example, can suck dust in.

Dust-reducing systems are built-in to many modern DSLRs (look for the 'sensor cleaning' message on the screen as you turn the camera on and off) and these do a decent job of shaking light dust particles from the sensor by vibrating it at ultrasonic speeds.

Before and after

Before you clean your sensor, take a test shot. Pop on a lens, stop it down to f/22, and take a photo of the sky during the day (taking care not to aim at the Sun of course) or a plain white wall, then increase the contrast in an editing app. The resulting image won't be the finest you've ever taken – in fact it will probably be a noisy mess – but it will highlight the condition of your

TOOLS AND **MATERIALS**

Cleaning kit, air blower and brush, a positionable light or a head torch, clean cloth, clean working environment.

WARNING

We do not recommend you use the cans of compressed air commonly used to blast dust out of keyboards, as these can introduce moisture into the electronics of your camera.

ALL PICTURES: IAN EVENDEN

camera sensor. The dust becomes more noticeable the more you close down the lens aperture and sticks out most on a plain light background.

With a magnifying glass or loupe, you will be able to identify individual specks of dust on the sensor using the image you just took as a guide – note that specks at the bottom of the sensor will be at the top of the picture. But taking the photo is really more useful to determine the state of the sensor. If dust is visible on the f/22 image, but not on images taken at f/2.8 or f/8, then you should consider leaving it alone until the specks become a problem. And once you've cleaned your sensor, you can take another f/22 photo to see the difference you've made.

The right tools

For large or stubborn dust particles, cleaning kits are available from most photographic retailers or online, and generally consist of a small bottle of cleaning solution and some brushes or swabs. Alternatively, a dry electrostatic brush can be used that the dust will stick to. Using the right sort of cleaning material is important, as a DSLR sensor is delicate and a scratch to its surface will do more damage than any amount of dust. Don't be tempted to dive in with a paintbrush, a lens cleaning brush, or anything that could damage the sensitive chip.

It's possible to clean a sensor without touching it at all. Lightly attached particles of dust can be removed using a blast of air. Special blowers are available for this, some shaped pleasingly like a rocket. Hold the camera with the lens mount pointing down, then blow air up into the camera. Dislodged dust will then drift down under the force of gravity.

Before you begin, clean the outside of your camera and the area you're going to work in. This is important to prevent you from adding more dust to the sensor than you remove. If you're using a blower, keep it in a sealed plastic bag so it doesn't collect dust and blow it into your camera's innards.

You'll also want to make sure your camera battery is charged, as it will be on and holding its mirror open throughout the cleaning process.

Ian Evenden is a journalist working in the fields of science, technology and photography

STEP-BY-STEP GUIDE

STEP 1

Expose the sensor. Most DSLRs have a cleaning option in their menus, though all models and manufacturers are different, so persevere or check the manual. Find it, and the mirror will flip back. Using a blower at this point will dislodge any lightly attached particles.

STEP 2

Lightly drag an electrostatic brush back and forth across the sensor – don't scrub or dab as if you're applying paint – then remove it without catching it on the lens mount and knocking the dust off. Never touch the bristles.

STEP 3

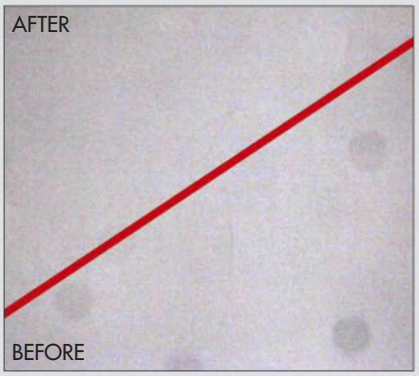
Squeeze a few drops of cleaning solution onto a swab, not onto the sensor. You need just enough to make it damp, not so much that it will drip off when held upside down. The fluid will evaporate quickly, so don't hang about.

STEP 4

Place the swab gently on the sensor and move it from side to side. The kits are tailored to the kind of sensor you have (usually APS-C or full frame) so it should be the right size and you won't have to wiggle it about for coverage.

STEP 5

When you've completed a wipe in one direction, turn the swab through 90°, flip it over so you're using the clean side, and clean in the other direction. Once this is done, remove the swab and dispose of it. Don't be tempted to reuse them.



STEP 6

You're done. Turn the camera off and the mirror should flip back into position. Attach a lens, switch it back on again, and take another reference photo to admire your work. The image above shows the same area of a sensor before and after cleaning.

With **Steve Richards**

Image PROCESSING

Understanding and using dark frames

Although in the excitement of the moment it is all too easy to forget about calibrating your images, the rewards of carrying out this task far outweigh the extra time required to do so. Dark frames play an important part in the production of quality deep-sky images, removing unwanted noise artefacts.

As your camera's sensor warms up during the long exposures required for deep-sky imaging, the temperature increase is misinterpreted as light, producing thermal noise that is overlaid on your image data. Longer exposures generate greater levels of thermal noise, especially with DSLR cameras as these don't have the benefit of a Peltier cooling system to keep them at a temperature many degrees below ambient.

Thermal noise has two different forms: an overall mush of noise and the more obvious 'hot pixels' that show as bright dots of light. Dark frames – that is, frames taken with the same settings as your main image frames but with the lens cap on – can help you to deal with this. It is important that dark frames should match the parameters used for capturing your deep-sky images with regard to exposure length, ISO number (where appropriate) and temperature. This ensures that the noise profile of the two image types can cancel one another out during the calibration process, thus removing the thermal noise to a large extent.

Matching parameters

The exposure length and ISO are easy to replicate, but temperature is harder to match with a DSLR camera than with an astronomical CCD that has Peltier cooling. With a DSLR camera you should capture your dark frames in similar ambient conditions to your image frames, ideally during the same imaging session.

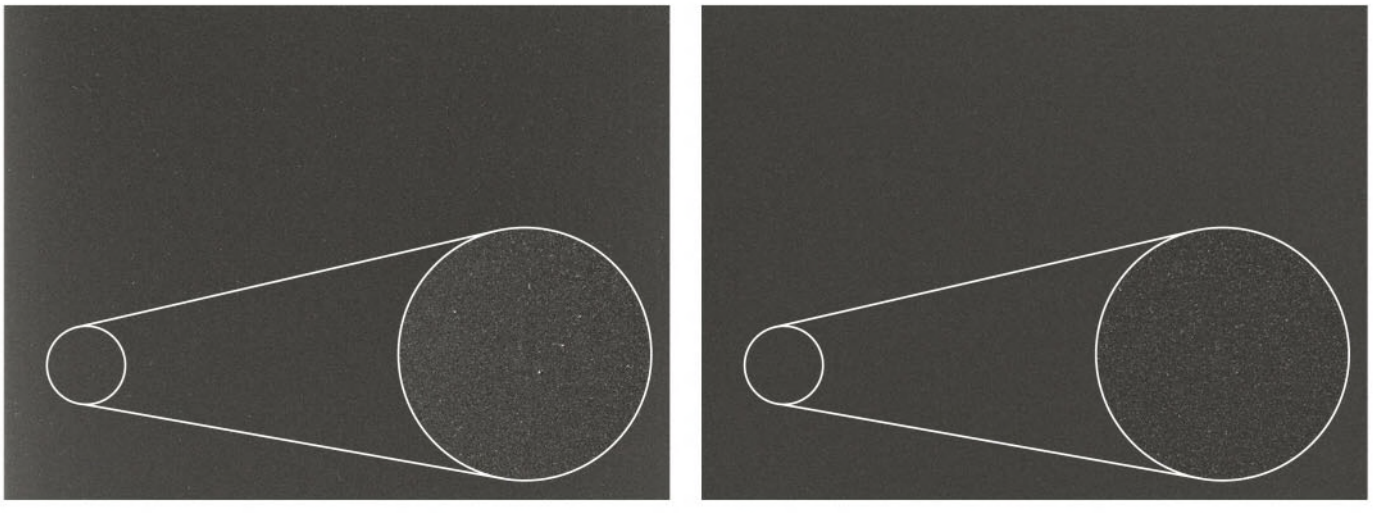
If your CCD has set-point cooling you can use what are known as 'library darks'. These are a set of dark frames taken at some previous time that can be re-used again and again, although you should refresh them every six months or so to compensate for ageing in the sensor. You should store a range of dark frames taken at different exposure lengths to ensure an accurate match to subsequent image frames.

You should aim to capture 16-30 dark frames for conversion into a single master frame to average out the noise artefacts and increase the signal to noise ratio. This ensures that the dark frame doesn't add any unwanted noise of its own to your images.

You download your dark frames from a camera in exactly the same way as your image frames so, in addition to holding a facsimile of the thermal noise profile of your sensor, dark frames also hold the bias data for your sensor. As both bias frames and dark frames need to be subtracted from your images during calibration, you can also use your dark frames to bias correct your images. However, if you are calibrating with flat frames, as we discussed last month, a set of bias frames will still be required to calibrate the flats.

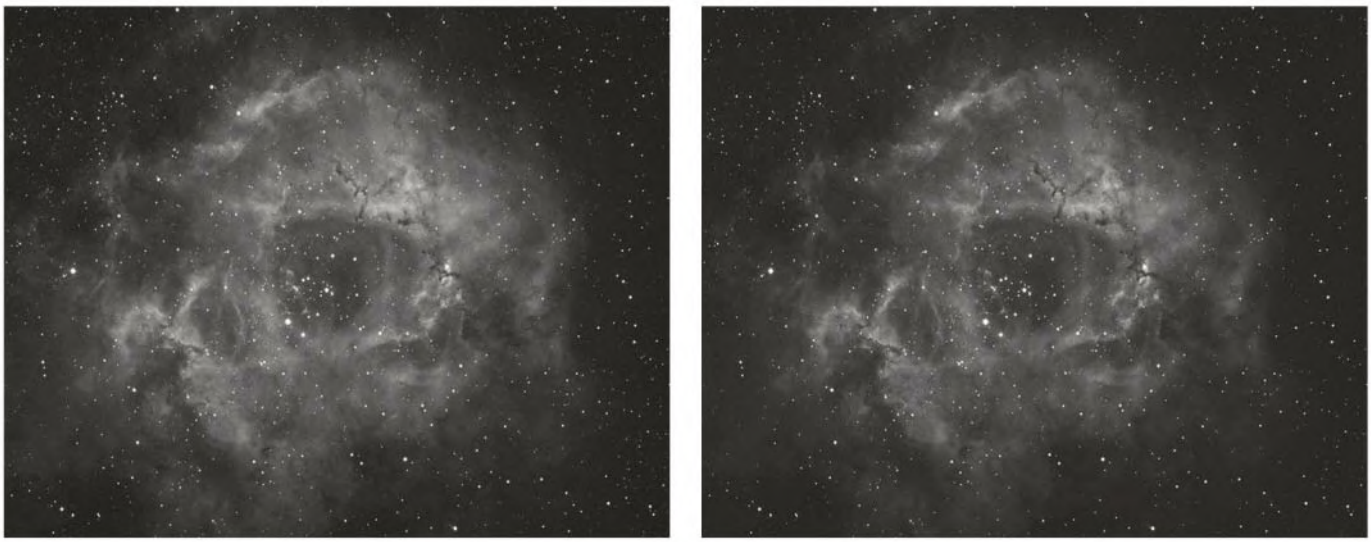
Although there are numerous programs that can be used to apply dark frames, here we're going to concentrate on two popular packages – DeepSkyStacker (free) and MaxIm DL (commercial).

In DeepSkyStacker, select the calibration files along with the image data files by clicking, in turn, **Open Picture Files > Dark Files**; **Flat Files**; **Dark Flat Files**; and finally **Offset/Bias Files**. Of course, if you are only applying dark frames, you can ignore the other



ALL PICTURES: STEVE RICHARDS

▲ **A single dark frame (left) displays much more random noise than a stacked master dark frame (right) – as is clear to see in the blown up areas**



▲ The Rosette Nebula in hydrogen-alpha, before dark frame calibration (left) and with reduced thermal noise after it has been applied (right)

▲ Our finished Rosette Nebula image, a bi-colour shot produced from dark-frame calibrated hydrogen-alpha and oxygen III data

calibration sets. The chosen data files are then selected for the final processing by clicking on **Check All**. DeepSkyStacker's default parameters work very well, so simply select **Register Checked Pictures** and tick the **Stack After Registering** check box. Finally, click **OK** to calibrate and stack the images.

MaxIm DL uses a two-part process in which the dark frames are first stacked to produce master darks, which are then applied to the image frames automatically prior to stacking them. A typical dark frame displays random noise; a master dark frame is considerably cleaner. Click **Process** > **Stack** > **Add Files**, choose the files you want to process, tick the **Auto Calibrate** check box. Then click on the Align tab and choose **Auto – Star Matching**. Navigate to the Combine tab and choose **SD Mask**. Finally click the **Go** button.

Steve Richards is a keen astro imager and astronomy equipment expert

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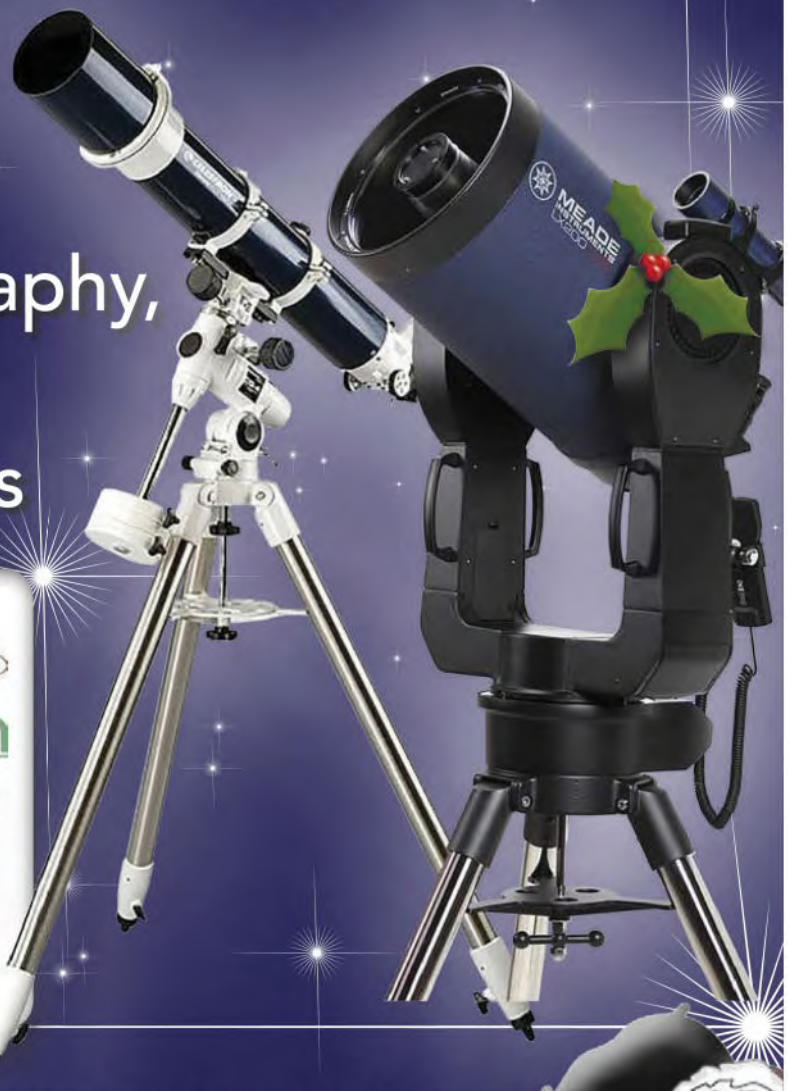

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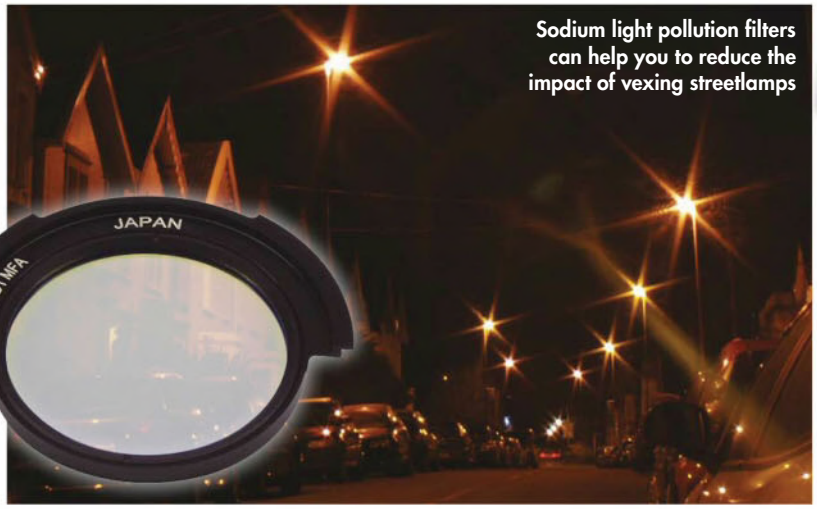

Sodium light pollution filters can help you to reduce the impact of vexing streetlamps

Are there any sodium light pollution filters I can use with my Canon EOS 700D 'virtual telescope', made up of camera lenses?

RICHARD A MAJOR

Sodium streetlights are the plague of many an astronomer, whatever apparatus they use. Luckily, they only emit light across a very narrow wavelength band, and so eliminating the glow can be easily done with a filter without sacrificing your light gathering power. As you have discovered, conventional screw-in 2- and 1.25-inch light pollution filters can't be fitted to your camera but there are some solutions.

Assuming that you use an unmodified DSLR camera, the choices are a little limited. However, Hutech produces an excellent light pollution filter called an IDAS LPS-D1 light pollution clip filter, which is compatible with your Canon DSLR camera. This filter controls sodium light pollution very convincingly without contributing much in the way of a colour cast to your images. The filter is housed in a special holder that installs inside the camera between the camera's lens bayonet and the flip mirror. This filter is also very suitable for a full-spectrum modified DSLR.

Some people modify their cameras to remove the standard infrared filter as it cuts out a lot of red light, including the all important hydrogen-alpha wavelength. If you have modified your camera, then consider the Astronomik CLS clip filter as it gives a very good boost to contrast to alleviate light pollution. As an alternative, you could use Astronomik hydrogen-alpha and oxygen III narrowband clip filters to capture mono or false colour images.

STEVE MARSH, WWW.TAVCSO.HU, ISTOCK

STEVE'S TOP TIP

Why should I use a red light torch?

It takes around 30 minutes for your eyes to become fully dark adapted and at their most sensitive for observing the night sky. Even a short flash of light can be enough to reverse this process in an instant so it is important to avoid normal white lights once dark-adapted. But, how do you find your eyepieces or read a sky chart in the dark? A red torch is your best friend here as the night-time receptors in your eyes (cells known as 'rods') are not very sensitive to this colour of light, so you won't destroy your hard won dark adaptation.

I often suffer from back pain while observing. Any advice on how to ease the strain?

CARL CLARKE

▲ A drummer's stool offers both padding and good adjustment

Observing through a telescope can certainly make you place your body in a whole range of contorted positions, guaranteed to give you back and neck pains! Observing from a seated position will help enormously but the type of telescope can dictate the seating arrangements.

Short refractors, Schmidt-Cassegrains and Maksutov-Cassegrains are easier to accommodate than Newtonian reflectors as the range of movement of the eyepiece with regard to the elevation of the object is less. A popular solution is to use a drummer's stool, as this is comfortably padded but has a reasonable range of height adjustment. You should position and adjust the stool so that your back is straight and you are not leaning forward to look into the eyepiece.

For a Newtonian reflector with its wide range of eyepiece positioning, you should adjust the focuser so that you look down into it at an angle and use an astronomer's observing chair like the Berlebach Charon, TS Astro Chair or Sky-Watcher Anti-Tip Observing Chair.

Steve Richards is a keen astro imager and an astronomy equipment expert

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★★★★★ Very good
★★★★★ Good
★★★★★ Average
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The colossus that is the 24-inch SkyVision T600 truss Dobsonian

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Find out more about how we review equipment at: **www.skyatnightmagazine.com/scoring-categories**

FIRST **light**

SkyVision 24-inch T600 Compact Go-To Dobsonian

A mighty truss Dobsonian with a colossal aperture and smooth tracking

WORDS: MARTIN LEWIS

SKY SAYS...
Tracking showed no signs of slippage or stalling, which can be a problem with driven large-aperture Dobsonians

VITAL STATS

- **Price** 1,999.99
- **Aperture** 600mm (24 inches)
- **Focal length** 1,980mm (f/3.3)
- **Focuser** Starlight Feather Touch
- **Go-To system** StellarCAT and Sky Commander user interface
- **Weight** 99kg
- **Supplier** Altair Astro
- **www.**altairastro.com
- **Tel** 01263 731505

ALL PICTURES: NICK ALTAIR/WWW.ALTAIRASTRO.COM

If you want the finest deep-sky views, you need large, photon-grabbing optics of a high quality. The SkyVision T600 Compact Dobsonian with its whopping 24-inch diameter mirror is that big aperture telescope. It can be broken into manageable parts that fit into a family car, allowing you to travel away from city lights to get the very best views of the heavens. The instrument also has full Go-To capability and motorised tracking to further enhance your observing experience.

Even a cursory look at this telescope shows it clearly to be a beautiful and elegant piece of engineering, and you can see a huge amount of thought and effort has gone into its design and construction. The scope comes in four main parts: a rocker box, primary box, truss pole set and secondary cage. The heaviest and largest part by far is the primary box, which contains the 36kg main mirror, onto which the large horseshoe-shaped altitude bearings are attached. This part weighs in at a hefty 69kg and needs to be carefully lowered into the rocker box – definitely a two-person operation. After attaching the linked truss pole set to the corners of the primary box with four quick-release levers, we were ready to mount the secondary cage on top of the poles. This item is a much more reasonable weight, and there are handy ledges to rest the cage on before securing the catches, so it is easy enough to do alone.

After removing the lightweight primary cover and fitting the Lycra shroud, the scope needed a small tweak using a laser collimator and the centre spotted mirror. We could have started observing right then, but chose to use the full Go-To capability by aligning on two bright stars and engaging the azimuth and altitude motor clutches. We then used the Sky Commander unit to drive the scope to a number of deep-sky objects. Each object was well within the field of a 6mm Ethos eyepiece, a testament to the quality of the Go-To system.

Tracking showed no signs of slippage or stalling, which can be a problem with driven large-aperture Dobsonians. However, we did witness objects slowly drifting from the centre of the field. This was subsequently traced to an incorrect latitude setting, which was still set to that of SkyVison headquarters near Bordeaux.

Touring the sky with Go-To

The first object we viewed was the Ring Nebula, high overhead, which was big and bright in the 6mm eyepiece. Using the same eyepiece we turned to M13 and M15, two of the finest globular clusters in the sky, which were easily resolved to their cores. ▸

GO-TO CAPABILITY AND TRACKING

The usefulness of a scope of this size is dramatically improved by the use of digital setting circles along with a good motorised system to slew to objects and keep them in the field of view.

The SkyVision T600 has a StellarCAT Go-To motor system married to a Sky Commander unit, although other digital setting circles such as ArgoNavis can be used instead. The success of any such system on a big Dobsonian telescope is dependent on the degree of care taken in the design, in particular the mechanics linking the motors to the scope and the control of the friction in the altitude and azimuth bearings. The whole drive system has been very well designed and manufactured so when engaged the drive system works without slipping with minimal backlash. When disengaged, the scope can be easily and smoothly pushed to targets like a conventional, undriven Dobsonian. In this manual mode the encoders stay linked so that you don't lose alignment and you can re-engage the motors at any time.

FOCUSER

The choice of focuser is one of the decisions to be made at time of purchase, but the default option is a Starlight Feather Touch with normal and slow speed knobs. The beautiful engineering on this focuser complements that of the rest of the telescope.

TRUSS POLES

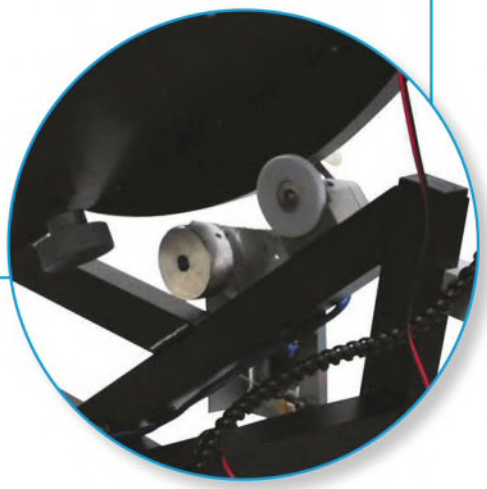
The carbon fibre truss poles are a work of art in themselves and exemplify the attention to detail present throughout the instrument. Each is 27mm in diameter and they link together in a single expandable set, which readily locks into position with quick-release levers.

THERMAL MANAGEMENT

The large mirror contains a lot of glass, so to help it acclimatise to night-time temperature there are two 100mm fans in the side of the mirror box. These blow ambient air onto the side and underside of the mirror to cool it down.

BEARINGS

The azimuth bearings are PTFE pads riding on FRP glass board, a standard combination for many large-aperture Dobsonians. The altitude bearings are quite different and are special rollers with a friction preload originally designed for CNC machine tools.



FIRST **light**

OPTICS

The 24-inch primary mirror is made of low-expansion Suprax glass and possesses high reflectivity coatings. The mirror sits on an 18-point support cell and is beautifully finished with no visible streaks plus a perfectly ground edge bevel. The telescope has a short focal ratio of f/3.3 to keep the eyepiece height low.

▸ Another memorable view was the Dumbbell Nebula, which we glimpsed through a binoviewer and a pair of 24mm Panotic eyepieces. The nebula had a mesmerising 3D appearance and was truly wonderful. With this setup we moved on to the Blue Snowball planetary nebula, which showed clear inner structure even at this low magnification. We followed our deep-sky viewing with some star testing, which showed smooth optics but signs of minor overcorrection – this may have disappeared with further cooling of the primary mirror.

The secondary mirror is quite exposed at the top of the secondary cage, and this led to it dewing up part of the way through our observing session. To drive off the dew we had to warm it up using the mirror's 12V rear heater. A lightweight extension to the top of the secondary cage might have helped delay such dewing – and if fitted opposite the eyepiece would also have blocked extraneous light reaching the eyepiece from the sky behind the secondary mirror. A significant portion of sky can be seen with the eyepiece removed. Such direct light could reduce field contrast if a bright object were to rest in this area of the sky.

All in all the SkyVision T600 is an advanced scope for serious visual observers and delivers great performance in a beautifully crafted instrument that is a joy to look at and a pleasure to use. S

VERDICT

BUILD & DESIGN	★★★★★
EASE OF USE	★★★★★
FEATURES	★★★★½
GO-TO/TRACKING ACCURACY	★★★★★
OPTICS	★★★★½
OVERALL	★★★★★

SKY SAYS...
Now add these:

1. Altair custom breathable scope cover

2. Kendrick Micro dew controller

3. Altair 10x60 RACI finderscope

ALL PICTURES: NICK ALTAIR/WWW.ALTAIRASTRO.COM

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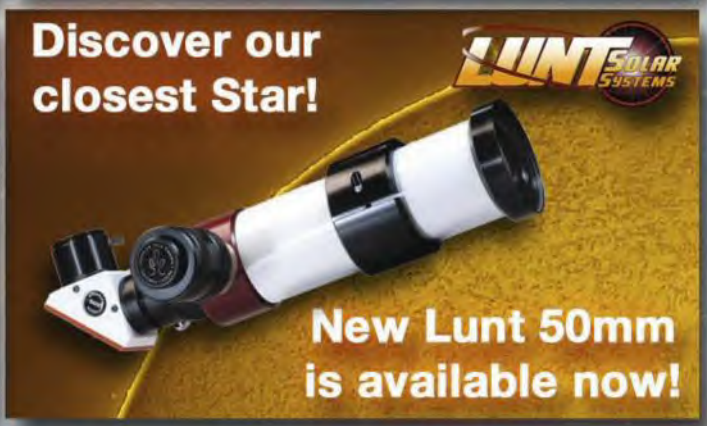

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FIRST **light**

See an interactive 360° model of these eyepieces at **www.skyatnightmagazine.com/Delite**

Tele Vue DeLite eyepiece range

This trio of parfocal lenses live up to their name – they are a delight

WORDS: PETE LAWRENCE

VITAL STATS

- **Price** £229 each
- **Focal length** 7mm, 11mm and 18.2mm
- **Apparent FOV** 62°
- **Eye relief** 20mm
- **Field stop** 7.5mm (7mm eyepiece); 1.1mm (11mm); 19.1mm (18.2mm)
- **Barrel size** 1.25-inch
- **Extras** Rubber eyecup, extendable eye guard (both built-in)
- **Weight** 0.20-0.22kg
- **Supplier** Telescope House
- **www.**telescopehouse.com
- **Tel** 01342 837098

WWW.THESECRETSTUDIO.NET X 4

If you're into visual observing, then the quality of eyepiece you use is an important issue. Optical quality can make or break an observation, but your comfort is also very important. If you're squinting down a narrow viewing cone, this can become stressful and prevent you from seeing what you're looking for.

The DeLite eyepiece series from Tele Vue delivers an optically excellent view together with the option to physically adjust the distance of your eye from the eye lens, whether you wear glasses or not. This makes it really easy to place your eye at the correct 'eye relief' to get the best view possible. The eye relief is the distance your eye must sit from the outer optical face of the eye lens in order to get the intended full angle field of view. Any closer or further from the lens surface and the view becomes more restricted.

The range includes eyepieces with focal lengths of 7mm, 11mm and 18.2mm. Each has the same 62° field of view, which we were able to verify by timing how long it took for a star to drift across each eyepiece's field with our mount's right ascension drive turned off. Stars looked sharp through the DeLites and showed little or no false colour; a small flash of blue was seen in the 18.2mm, but only at the extreme edge of the field and only with a very bright star in view.

SKY SAYS...
The Moon was exquisite. Intricate details along the terminator were sharp and full of detail

The view of the Moon was exquisite. Intricate details visible along the terminator were sharp and full of detail. Our views of the craters Hevelius and Grimaldi were quite amazing. The high contrast delivered by the 18.2mm eyepiece was superb, but our favourite view was through the 7mm. The inky dark of the lunar night, contrasting with the bright lunar highlands at high magnification, just kept inviting us to keep exploring.

An unforgiving test

Stars are unforgiving test subjects. Their pin-point light will cause any optical aberrations to stand out like a sore thumb, especially at the edge of frame, and our test 4-inch apochromatic refractor had excellent optics – leaving the DeLite eyepieces nowhere to hide. Fortunately, they delivered in spades and the quality of the view was first class.

The 18.2mm eyepiece showed us a large swathe of the Andromeda Galaxy and – with excellent contrast – the dark dust lane truncating one side of the galaxy's core was very clear. Satellite galaxy M32 was an easy spot and dimmer M110 quite straightforward to see too. The 11mm gave the best view, bringing us closer in while maintaining contrast. ▸

A COMFORTABLE VIEW – WITH AND WITHOUT GLASSES

The DeLite eyepieces deliver a fantastic image, free from aberration and very crisp – exactly what a good eyepiece should do. The 62° multicoated field of view is superb and, placing your eye at the correct eye relief distance of 20mm ensures you get all of that view, just as intended. We really appreciated the extending and lockable eye guard that provides an accurate and repeatable way to do this without fuss.

The lockable eyeguard and 20mm eye relief means that the DeLites are perfect for those who swap between wearing spectacles too. Their adjustment means it's possible to set them for optimum views with or without spectacles in place. Green markers on the side of the eyepiece barrel provide a convenient way to reproduce the same eye guard position each and every time.

Ultimately, the excellent design of the DeLites provides an eyepiece that you forget about. Instead you find yourself concentrating on the thing your telescope has been pointed at, and this, after all, is what a telescope and its supporting optics are supposed to do.

PARFOCAL NATURE

These eyepieces are parfocal, meaning that once focused on your target, you can swap between them without having to significantly refocus. In practice, we found swapping between the 18.2mm and either of the others required the most focus tweaking. The 11mm and 7mm were very close to one another.

RUBBER EYECUP

Each eyepiece is equipped with a roll-back rubber eyecup. This creates a comfortable interface between your eye and the eyepiece, and closes the gap between them to keep things good and dark. The soft rubber also allows spectacles to be kept on without fear of scratching them.

1.25-INCH BARREL

The eyepieces will fit a 1.25-inch eyepiece holder. Each barrel is shaped to provide a safety ridge. Should a screw become loose, the expensive eyepiece is less likely to fall to the ground if the telescope swings into a position where gravity takes hold.

THREADED 1.25-INCH BARREL

All three 1.25-inch eyepiece barrels are internally threaded so that filters can be screwed into them. This is useful if you want to, say, add a colour filter to the eyepiece to bring out more detail such as features in a planet's atmosphere or increase the contrast of a faint nebula.

FIRST **light**

▸ The bright star cloud NGC 206, embedded in M31's southwest arm, was also easy to see with the 11mm eyepiece using our 4-inch test scope. The 7mm's contrast was lower and didn't really suit our 130x magnification view of M31, although it gave us a good view of M32. M110 was harder to pull out of the background sky but could still just be seen.

Through the 18.2mm eyepiece, Albireo in Cygnus showed deep, rich colours – a beautiful golden yellow primary and azure blue secondary. However, at 50x magnification we wanted something with a bit more power. The 7mm got right into the action, splitting both stars well, but with reduced colour intensity. It was the 11mm that really delivered for this target, giving good image scale and deep colour.

The famous Double-Double, Epsilon Lyrae, flipped the situation. Here, the 18.2mm easily split the well-separated main pair, but splitting these again into their tight components was a struggle at 50x. The 85x magnification delivered by the 11mm showed each main component to be elongated. Over time, the comfortable, relaxed view allowed us to see that the elongations were composed of two tiny pin-pricks of light side by side. Moving the Double-Double to the edge of frame also maintained this view – a great testament to the quality of the optics. The 7mm, of course, split both pairs with relative ease.

These are superb eyepieces, conveniently sized and light. Individually, like their name, they are a delight to use. However, they will tug at your wallet strings and you'll soon be wanting the whole set. S

VERDICT

BUILD & DESIGN	★★★★★
EASE OF USE	★★★★★
EXTRAS	★★★★★
EYE RELIEF	★★★★★
OPTICS	★★★★★
OVERALL	★★★★★

SKY SAYS...
Now add these:

1. Tele Vue Bandmate planetary filter
2. Revelation Self Centring 2- to 1.25-inch adaptor
3. Tele Vue 2x Barlow lens

EXTENDABLE EYE GUARD

Each eyepiece's outer barrel can be unlocked and extended to just the right length to put your eye at 20mm from the outer surface of the eye lens, at the eye relief of the eyepiece. This ensures you get precisely the 62° apparent field of view the eyepiece was designed to deliver.

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FIRST **light**

See an interactive 360° model of this camera at **www.skyatnightmagazine.com/4120EX**

Atik 4120EX colour CCD camera

A great CCD for DSLR users who want to upgrade but still keep it simple

WORDS: STEVE RICHARDS

VITAL STATS

- **Price** £1,999.99
- **Sensor** Sony ICX834AQG colour
- **Sensor size** 15.8mm diagonal
- **Pixels** 4,242x2,830; 3.1µm square
- **Readout noise** 5e
- **Backfocus** 13mm
- **Weight** 381g
- **Supplier** Atik Cameras
- **www.**atik-cameras.com
- **Tel** 01603 740397

SKY SAYS...
We were reminded of how convenient a colour camera can be under fickle UK skies

The arrival of the Atik 4120EX CCD camera may raise an eyebrow from some deep-sky astrophotographers, as a little unusually only a colour version is available, with no monochrome alternative.

Mono CCDs require a set of three external colour filters and three different sets of exposures to produce a colour image. A luminance channel captured using a plain filter normally supplements these three colour 'channels'. Colour CCDs, however, have a matrix of colour filters sublimated on the sensor's surface, allowing them to capture all three colours in a single 'shot'.

Mono CCD cameras are more popular as they produce slightly higher definition images and allow the use of narrowband filters to capture specific wavelengths of light without the impediment of the built-in filters. However, when clear skies are at a premium, colour CCD cameras have a big advantage of being able to capture a usable full colour image in a short period of time, making good use of short, cloud-free spells.

The appearance of the 4120EX follows Atik's usual style, comprising a cleanly designed and beautifully executed electric red anodised aluminium cylinder with satin black trim. The accessories include a 1.25-inch nosepiece, 12V cigar lighter power cable, USB cable, a software CD, a multi-product user guide a small tool that allows you to remove the circular plug on the side of the sensor chamber for desiccant replenishment. The complete kit is supplied in a printed retail box.

The software CD includes drivers for AstroArt, CCDSoft, MaxIm DL and the universal standard ASCOM platform. Also included on it are Atik's popular Artemis (image capture) and Dawn (image processing) programs, along with some short videos showing you how to use them. We elected to use the ASCOM driver as this allowed us to test the camera for general compatibility. Both the installation and software integration with our own MaxIm DL image capture software were quick and easy on our desktop computer running Windows XP.

Critical cooling

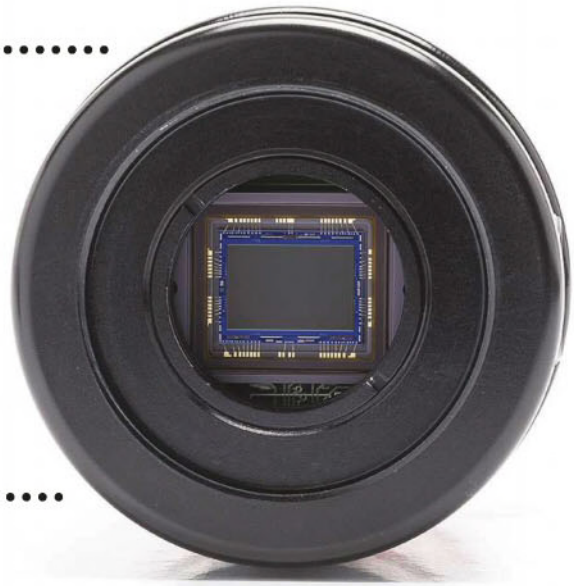
The camera has set-point cooling, which allows you to set a sensor cooling temperature (known as 'delta T') to as low as 25°C below the ambient temperature. Part of our testing took place in early September and on a couple of warm nights, we were unable to achieve cooling temperatures lower than –9°C (a delta T of –27°C). This could be an issue for some users during the summer months, but we were happy with the low-noise results ▸

GENEROUS COLOUR SENSOR

The new ATIK 4120EX is a bit of a departure from ATIK's most popular cameras as it is equipped with a Sony ICX834AQG CCD sensor, which is only available as a colour variant. The sensor has a repeating matrix of red, green and blue filters on its surface, so light is filtered before it falls on the individual photosites that make up the sensor.

Downloaded images appear to be in mono, but the colour information is encoded into what is known as a Bayer Matrix that can be decoded later, using software, by a process known as de-Bayering. This process extracts the colour data from the mono image and uses a certain amount of interpolation to construct the final colour image. This method is exactly the same as that in a DSLR camera, although a DSLR has a built-in processor to carry out the de-Bayering.

The sensor is a very generous 13.2x8.8mm in size comprising 3.1µm pixels in an array measuring 4,242x2,830 pixels. This produces high-resolution images, making this camera a good choice for wide-field imaging.



SIMPLE CONNECTIONS

The uncluttered rear panel of the Atik 4120EX only has two connections, a USB Mini-B for connection to a USB 2.0 port on a computer and a standard 12V DC socket for powering the internal control circuits and the single-stage Peltier cooling module. Unusually, there is not an ST-4 autoguiding port.

FAN-ASSISTED PELTIER COOLING

The Atik 4120EX uses a Peltier module to cool the sensor down to around 25°C below the ambient temperature to reduce the thermal noise generated by the sensor. There is also a cooling fan mounted on the rear of the casing to extract unwanted heat.

SLIM CASING

With a camera casing 60mm in diameter and weighing only 381g, the Atik 4120EX is certainly svelte. However, its colour sensor and slim profile make it ideal for mounting on the front of either a Fastar/HyperStar equipped Schmidt-Cassegrain or Rowe-Ackermann telescope without obstructing the light path.

DESICCANT PLUG

It is very important that the chamber housing the sensor is kept free from moisture, so that the sensor itself doesn't frost up when cold. The desiccant pellet that does this is accessed via a small plug. It will need to be rejuvenated from time to time by heating it in an oven, but is easily removed using the supplied tool.

FIRST light

▲ NGC 7000's 'Mexico region', imaged as six 600-second frames calibrated with bias, dark and flat frames

▸ achieved even at this temperature. It took just two minutes and 16 seconds to reach 25°C below the ambient temperature.

We carried out our imaging tests with the camera attached to our own William Optics FLT98 refractor which, with our 0.8x field flattener, has an effective focal length of 509mm. The camera's Sony ICX834AQG chip (which has a 15.8mm diagonal) gave us a generous wide field of view 1.5x1°, a good field size for many deep-sky objects.

The summer Milky Way was riding high in the sky during the review period so we captured a series of exposures of the 'Mexico region' of the North America Nebula in Cygnus. This object is rich in the hydrogen-alpha portion of the electromagnetic spectrum – it was important to confirm the sensitivity of the sensor to this all-important emission component and we were happy to be rewarded with a detailed and colourful image.

The camera operated faultlessly throughout the review period and we were reminded of how convenient a colour camera can be under fickle UK skies. There is no doubt that a monochrome camera, a filter wheel and a set of filters will give greater flexibility in deep-sky imaging, but these extras bump up the price of a setup considerably.

We would not hesitate to recommend the Atik 4120EX to beginners and DSLR imagers looking to upgrade their camera but not wishing to make the leap to monochrome imaging. S

1.25-INCH AND T-ADAPTOR

The camera is supplied with a 1.25-inch nosepiece rather than a 2-inch one, with a male T-thread to attach it to the camera. The female T-thread on the camera also allows it to be screwed onto a suitable T-extension tube, field flattener-reducer or coma corrector for a more substantial installation.

VERDICT

BUILD & DESIGN	★★★★★
CONNECTIVITY	★★★★☆
EASE OF USE	★★★★★
FEATURES	★★★★☆
IMAGING QUALITY	★★★★☆
OVERALL	★★★★☆

SKY SAYS...
Now add these:

1. Atik universal power supply
2. Atik off-axis guider
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Books

New astronomy and space titles reviewed

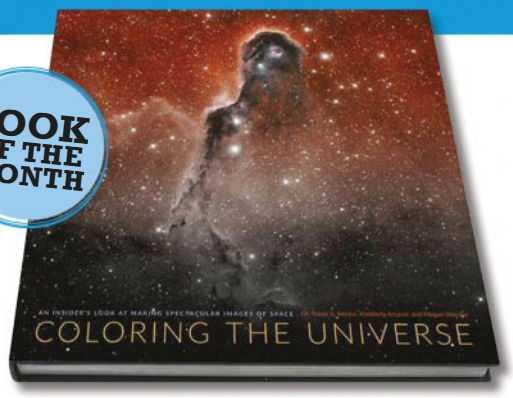
RATINGS

★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

Coloring the Universe

An Insider's Look at Making Spectacular Images of Space

BOOK OF THE MONTH



Travis Rector, Kimberly Arcand, Megan Watzke
University of Alaska Press
£35 ● HB

The back cover of *Coloring the Universe* sets out its pitch in no uncertain terms. "This is not your typical astronomy book," it proclaims, while the blurb goes on to distance the volume from "coffee table books full of pretty astronomy pictures". But if you're a fan of eye-popping space imagery don't be put off: this tome is bursting at the seams with some very pretty astronomy pictures indeed.

What singles this book out is how it lifts the curtain on the processes by which these spectacular images are made. There are explanations of the astrophysics of celestial objects, how telescopes and cameras capture and record light, as well as the software techniques used to create these striking images. But you'll also find discussions on the science of perception in the human eye and brain, as well as topics that veer into the realms of art theory. If you're curious to know why hydrogen is an important element in astronomy and how Hubble's iconic 1995 image Pillars of Creation owes a debt to 19th-Century landscape painting, you'll find the answers to such questions in these pages.

How much does the iconic Pillars of Creation image owe to landscape painting?

NASA/ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

The book is squarely aimed at the US market and this results in my only quibble: the resolute avoidance of metric units throughout the text. It surely wouldn't have hurt to include metric figures in brackets, if only as an insight into the language in which astronomy is actually conducted. But this is a very minor complaint. A nod must also go to the book's designers: it is beautifully laid out in a way that does full justice to the images, with some nice design flourishes that lend it the luxurious feel of an art monograph rather than a science textbook.

Whether you're an experienced astrophotographer or simply someone who loves beautiful space pictures and wants insight into how they're created, *Coloring the Universe* hits the spot. It's true that this is not your typical astronomy book, and after reading it you'll probably never look at an astronomy image in quite the same way again. Nevertheless, I can guarantee it's going to look amazing on your coffee table.

★★★★★

MAREK KUKULA *is the Royal Observatory Greenwich's Public Astronomer*

TWO MINUTES WITH TRAVIS RECTOR

What inspired you to write the book?
Over the past 20 years I have taken colour images of space with telescopes at Kitt Peak National Observatory and the Gemini Observatory, among others. My co-authors Kim Arcand and Megan Watzke work for NASA's Chandra X-Ray Observatory. People often ask us about the accuracy of the images and how they are made. We wanted to write a book that answers these questions and more.

How does the real Universe differ from the pictures seen in books?
Our pictures show real stars, galaxies and nebulae: they aren't the creative imaginations of graphic artists. But almost everything in space is too faint to see. You could fly a spaceship to the Horsehead Nebula and it would still look black. Telescopes are able to see objects over a billion times fainter than our eyes can, and they also allow us to see other kinds of light such as infrared, ultraviolet and X-rays.

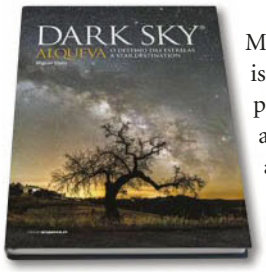
Why is it important to 'colour the Universe'?
How do we make a colour image out of X-rays; a kind of high-energy light our eyes can't see? This is one of the many examples we talk about in the book, where we create an image that allows us to observe what's happening in otherwise invisible yet very real data. The book contains over 300 images and each has a story as to how it was created, what it shows and what scientists can learn from it. We hope the book will help people better understand these beautiful images.

TRAVIS RECTOR *is an astronomer at the University of Alaska Anchorage*

Dark Sky Alqueva

A Star Destination

Miguel Claro
Centro Atlantico
28.85 ● HB



Miguel Claro is a professional photographer and the official astrophotographer of the Dark Sky Alqueva Reserve on the boundary of the Beja and Évora districts of southern Portugal. His photographs have appeared in international publications such as *National Geographic* and the NASA Astronomy Picture of the Day online gallery, as well as being twice shortlisted for the Insight Astronomy Photographer of the Year competition run by the Royal Observatory Greenwich.

In this book, Claro illustrates the stunning landscapes of the Alqueva Park with gorgeous panoramas of the Milky Way arching across the sky, along with beautiful vistas showing the wonder of what is a truly dark sky site. The beginning of the book contains an introduction to the dark sky reserve, highlighting amongst other things how humans have been gazing up in awe from that point for thousands of years, and then makes way for Claro's impressive, mainly wide field images.

More deep-sky images taken from the site might have provided additional appeal, but this is only a minor point. There is also no numbering on the pages, despite there being an index with illustrations of the images and their details at the back of the book. However, *Dark Sky Alqueva* is a fantastic collection of astro images and certainly makes a great case for visiting the region to enjoy the stunning views for yourself: I for one have already put it on my list of places to travel to!

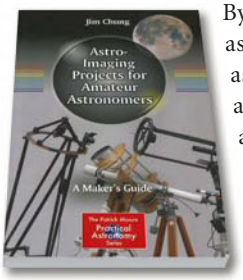
Dark Sky Alqueva is currently available via the publisher's website at www.centroatl.pt.

★★★★☆

PAUL MONEY *is* BBC Sky at Night Magazine's *reviews editor*

Astro-Imaging Projects for Amateur Astronomers

Jim Chung
Springer
£19.99 ● PB



By its very nature, astro imaging requires astronomers to modify, adapt and engineer a range of equipment to suit their very specific requirements, and as such most imagers usually have a project of some kind on the go.

In this book, Jim Chung details many of his own projects, even though some are pretty heavy going with regard to the materials used and as such are not suitable for all. However, it is always interesting to see how fellow astronomers tackle conversions that you may be considering yourself. Chung's folded refractor, for example, is enough to make any DIY-inspired astronomer reach for the bench saw.

The book is peppered with anecdotes that at times become ramblings and can be quite a distraction from the project in hand. In a different kind of book they might have made for interesting reading, but they seem out of place in a practical guide. Some nice examples of Chung's images, captured with modified equipment, are spread around the pages, but these are poorly reproduced, which is a pity as they would otherwise be a good demonstration of the value of the project that produced them.

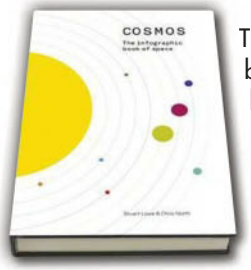
As an insight into another astronomer's world this is an interesting read, but if you are looking for a workbook suggesting a range of 'things to do and make' then, sadly, this isn't it. Rather, this book is the story of one astronomer's journey through the workshop as he tackles the reclamation of the discarded equipment that seems to find its way to his door.

★★★☆☆

STEVE RICHARDS *is an experienced astrophotographer and* BBC Sky at Night Magazine's *Scope Doctor*

Cosmos: The Infographic Book of Space

Stuart Lowe and Chris North
Aurum Press
£25 ● HB



This glossy and beautifully designed book explores all kinds of astronomical concepts, detailing the lives of stars and galaxies as well as alien worlds and comets. It also, as the title suggests, charts the history of world-class observatories and spacecraft with crisp and thoroughly researched infographics. Topics illustrated include the physical, such as lakes and mountains on Solar System planets, and the cosmological, like the makeup of the cosmos in terms of normal matter, mysterious dark matter and the dark energy accelerating the Universe's expansion.

The authors are scientists who met working on ESA's Planck satellite mission and they've taken part in many projects that promote astronomy to the public. They've done a great job; the passages that accompany the infographics in *Cosmos* are well written and clear.

Some of the visuals highlight little-known facts quite strikingly. One brings home the way the 'transit' method – looking for a tiny dimming of stars when planets pass in front of them as viewed from Earth – has flourished over the past few years. That's largely thanks to NASA's Kepler mission, which alone has found more than half of the confirmed exoplanets to date.

The graphics might not always appeal to scientific purists, however. They are very detailed and design-led, and sometimes you need to stare at them for some length to figure out what they're trying to convey. Nonetheless, *Cosmos* is richly packed with fascinating tidbits of information and makes a colourful, sleek addition to the bookshelves.

★★★★☆

HAZEL MUIR *is a freelance science writer*

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

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5 Universe2Go Personal Planetarium

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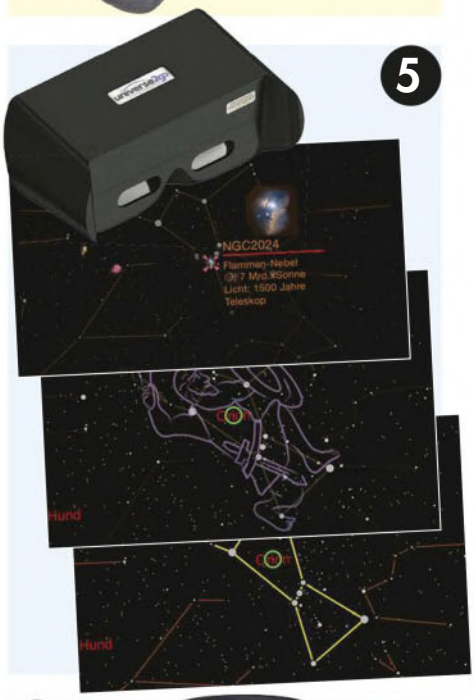

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WHAT I REALLY WANT TO KNOW IS...

What is Phaethon: a comet or an asteroid?

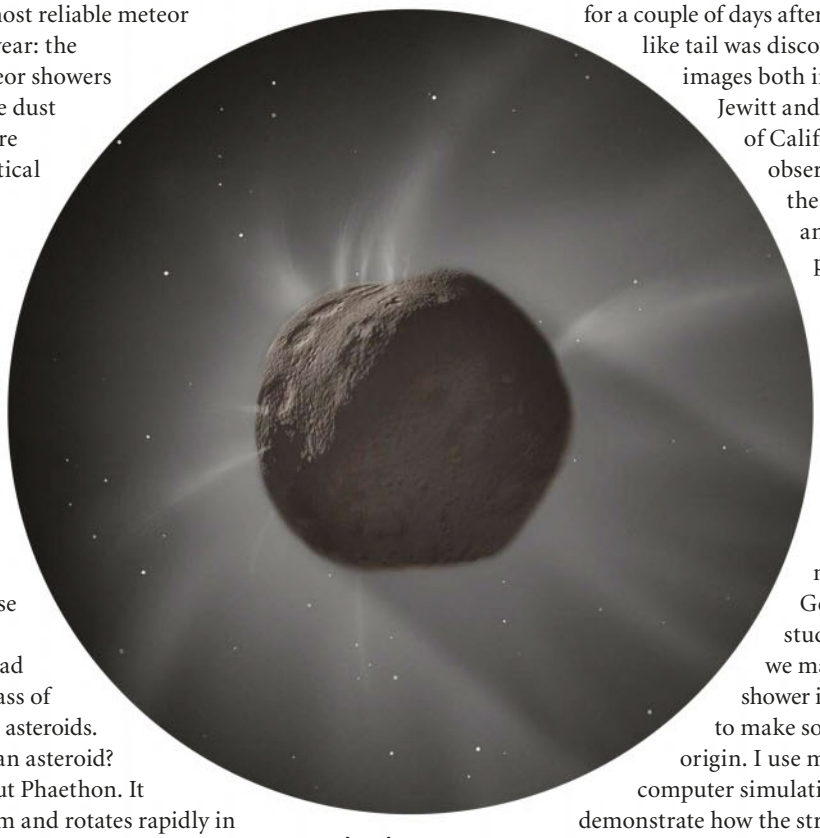
Galina Ryabova wonders why the celestial object behind the Geminids seems so unlike those that produced other showers

INTERVIEWED BY PAUL SUTHERLAND

December sees the return of one of the strongest and most reliable meteor showers of the year: the Geminids. Meteor showers are usually produced by the dust ejected by comets as they are warmed on their long elliptical orbits around the Sun. The parent comets for most important showers seen during the year have been identified, such as comet 109P/Swift-Tuttle for the summer Perseids.

The parent body of the Geminids was only identified in 1983, spotted in images taken by an infrared satellite called IRAS. Named Phaethon, the object came as a surprise because, unlike other meteoroid progenitors, it had more in common with a class of space rock called the Apollo asteroids. So is Phaethon a comet or an asteroid?

We don't know a lot about Phaethon. It has a diameter of about 5km and rotates rapidly in a period of around 3.6 hours, compared to a median rate for all asteroids of 8.5 hours. What is really interesting is that it rotates on its side, because its spin axis is angled only 2° above its orbital plane. It is classified as an F- or B-type asteroid, making it a stony type of rock called a carbonaceous chondrite, and we know its shape is not spherical.



Was Phaethon once a comet that turned into an asteroid or an asteroid with comet envy?

The problematic perihelion

This asteroid has very small perihelion distance, meaning it gets very close to the Sun, to a distance of only about 21 million km, and 2,000 years ago it got to less than 19 million km. No comet could survive for very long so close to the Sun. But perhaps a comet could be captured into this orbit, lose its volatiles (those chemical compounds with low boiling points), and so be turned into asteroid. There are asteroids known with even smaller perihelion distances than Phaethon. A quick search of the NASA JPL Small-Body Database reveals 31 of them.

Following its discovery in 1983, Phaethon at first showed no trace of activity. However it brightened by a factor of about three in June 2009 and May 2012, for a couple of days after perihelion. Later a comet-like tail was discovered on the asteroid images both in 2009 and 2012. David Jewitt and Jing Li, of the University of California, Los Angeles, observed this brightening via the STEREO-A spacecraft, and concluded that dust production resulting from thermal decomposition and thermal fracture of the asteroid was the most probable explanation.

The evidence is overwhelming that Phaethon is the parent body for the Geminids. And while we don't know much about Phaethon, the Geminids is one of the most studied meteoroid streams, so we may use observations of the shower it produces every December to make some conclusions about its origin. I use mathematical modelling, computer simulation in other words, to demonstrate how the stream was generated and subsequently evolved, then compare my model with the actual observations. The stream structure seems to show its cometary origin. The activity curve of its shower has two distinct peaks, and this is a feature that supports a cometary ejection model. I believe that Phaethon was a comet, captured on its present orbit. It lost volatiles at a catastrophic rate, over just one to three orbital revolutions, and is now an asteroid.

I have studied this stream for more than 35 years, but there is still more to be discovered. We have already made the most of old observational data. Now we need more 'high end' observational data, especially to give us individual meteoroids' orbits. Amateur astronomers can still play an important part in observing this shower.

My latest scientific paper on the Geminids is based on visual observations of the 2004 shower when a total of 29,077 Geminid meteors were detected in 612 hours of observing by amateur observers all over the world. But what I would really like to see, because it could answer many questions, is a space mission to Phaethon.

ABOUT GALINA RYABOVA

Prof Galina Ryabova, of the Institute of Applied Mathematics and Mechanics at Tomsk State University, Russia, is one of the world's leading authorities in meteor science and a keen supporter of professional-amateur collaboration via the International Meteor Organization.

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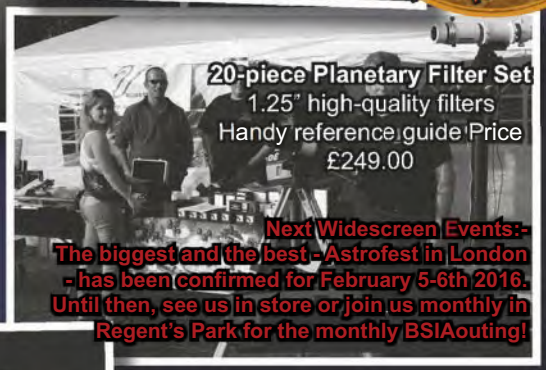

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Lunar photo by Widescreen customer Richard Maun. Main BSIA image by Tom Kerss. Sadr nebulosity by Geoffrey Lenox-Smith

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The Southern Hemisphere in December

With Glenn Dawes

WHEN TO USE THIS CHART

1 DEC AT 00:00 UT
15 DEC AT 23:00 UT
31 DEC AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

DECEMBER HIGHLIGHTS

Comet C/2013 US10 Catalina may be very impressive in the morning sky, possibly reaching 5th magnitude! The comet passed through perihelion in mid-November and has been rising slowly out of the solar glare ever since. Use Venus as a marker: on the 8th the comet is 4° below this beacon in the dawn sky, with the thin crescent Moon between them. The comet rises around 02:30 EST mid-month and can be enjoyed without moonlight from the 9th to the 22nd.

STARS AND CONSTELLATIONS

Canis Major is high in the eastern evening sky. It's hard to miss with its brilliant alpha star, Sirius, the brightest star in the whole sky at mag. –1.5. But it only holds this accolade because the star is a close 8.5 lightyears away. Canis Major contains two much more massive and distant naked-eye stars, mag. +1.8 Wezen and mag. +1.5 Adhara (Delta ( ) and Epsilon ( ) Canis Majoris). If they were at a similar distance to Sirius, they would each easily outshine Venus!

THE PLANETS

With the exception of Mercury, the bright planets reside in the morning sky. Jupiter rises near midnight mid-month, an hour after mag. +1.4 Regulus (Alpha (α) Leonis). Mars is the next arrival around 01:30 EST, rising with mag. +1.0 Spica (Alpha (α) Virginis) nearby. This is followed by Venus, appearing at around 03:00 EST. Saturn returns to the morning, rising out of the dawn glow. Turning to the evening, Mercury slowly gains altitude in the west-southwest, remaining low in the twilight.

DEEP-SKY OBJECTS

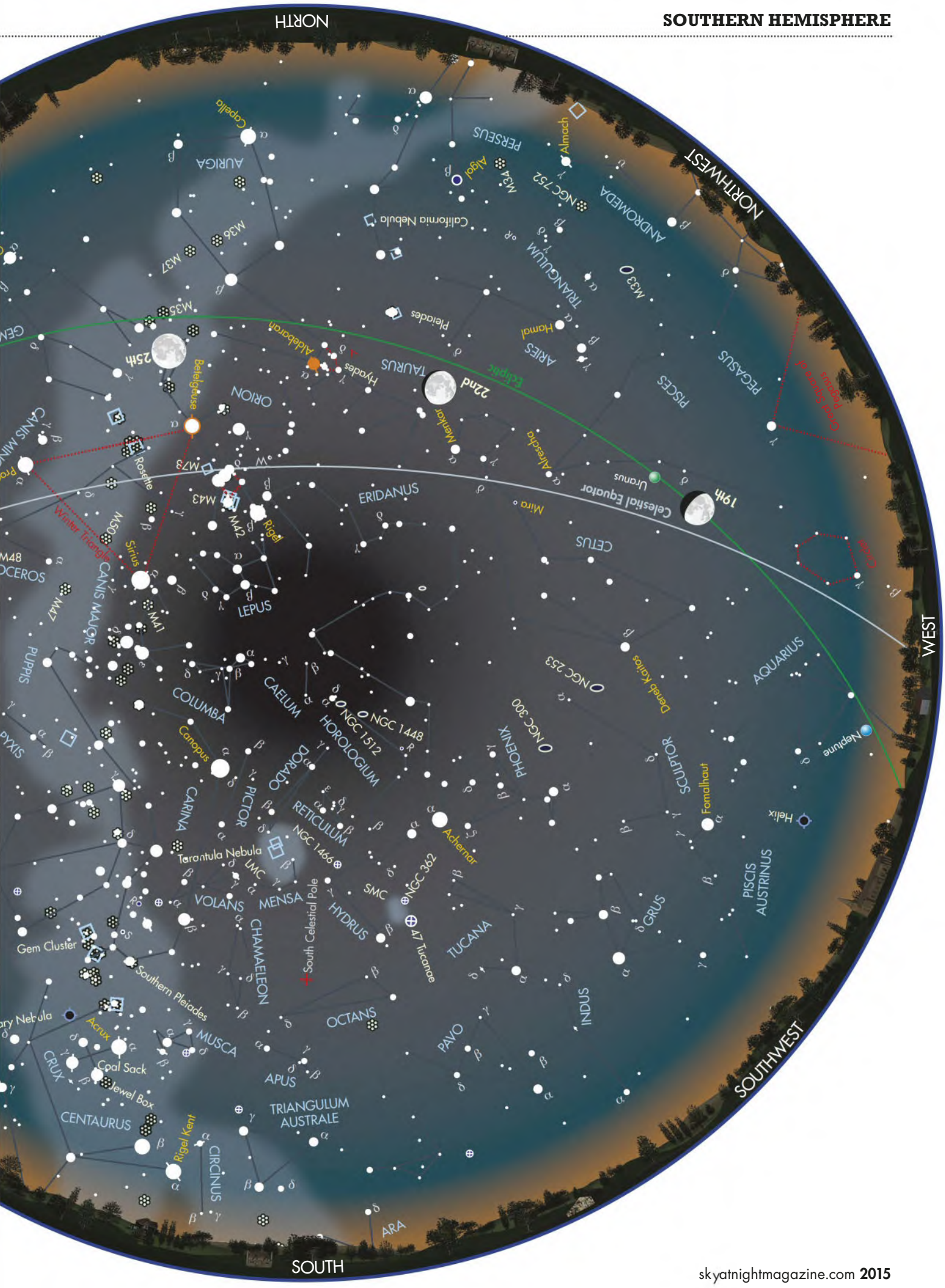
The constellation of Horologium is high in the southern sky. It is faint, its most distinctive feature being a naked-eye double star, mag. +3.8 Alpha (α) and mag. +4.9 Delta ( ) Horologii, which are 40 arcminutes apart. Through binoculars the former looks distinctly yellow, its companion white.

Horologium is known for its galaxies. Look 2° west and slightly south of Alpha Horologii to discover NGC 1512 (RA 4h 03.9m, dec. –43° 21'; pictured). This mag. +10.3 spiral galaxy has a distinctive bright bar, and appears as a 2x1-arcminute oval with a bright central region. Continue in this direction another 3.7° to edge-on spiral NGC 1448 (RA 3h 44.5m, dec. –44° 39'). Being able to say you've see this mag. +10.7 ghostly streak, around 4x0.5 arcminutes in size, is quite satisfying.

CHART KEY

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER


NORTH
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WEST
SOUTHWEST
SOUTH
Capella
AURIGA
PERSEUS
Almach
Algol
M34
NGC 752
ANDROMEDA
California Nebula
M36
M37
TRIANGULUM
M33
M35
Pleiades
Hamal
ARIES
PISCES
PEGASUS
Great Square of Pegasus
Aldebaran
Hyades
TAURUS
Ecliptic
22nd
Betelgeuse
ORION
Meissa
Alrescha
Rosette
M78
M43
M42
Rigel
ERIDANUS
Uranus
Celestial Equator
19h
Mira
Winter Triangle
Sirius
M50
CANIS MAJOR
CETUS
LEPUS
M41
M47
PUPPIS
COLUMBA
CAELUM
NGC 1448
NGC 1512
HOROLOGIUM
NGC 253
Denebb Kaitos
AQUARIUS
Canopus
PYXIS
CARINA
PICTOR
RETICULUM
NGC 1466
PHOENIX
NGC 300
SCULPTOR
Fomalhaut
Neptune
Helix
Achernar
Tarantula Nebula
LMC
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